FACILITATING AMERICAN SIGN LANGUAGE LEARNING FOR HEARING PARENTS OF DEAF CHILDREN VIA MOBILE DEVICES

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To my family,

your support has meant everything to me.

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SUMMARY

In the United States, between 90 and 95% of deaf children are born to hearing parents. In most circumstances, the birth of a deaf child is the first experience these parents have with American Sign Language (ASL) and the Deaf community. Many parents learn ASL as a second language to provide their children with language models and to be able to communicate with their children more effectively, but they face significant challenges.

To address these challenges, I have developed a mobile learning application, SMARTSign, to help parents of deaf children learn ASL vocabulary. I hypothesize that providing a method for parents to learn and practice ASL words associated with popular children's stories on their mobile phones would help improve their ASL vocabulary and abilities more than if words were grouped by theme. I posit that parents who learn vocabulary associated with children's stories will use the application more, which will lead to more exposure to ASL and more learned vocabulary.

My dissertation consists of three studies. First I show that novices are able to reproduce signs presented on mobile devices with high accuracy regardless of source video resolution. Next, I interviewed hearing parents with deaf children to discover what difficulties they have with current methods for learning ASL. When asked which methods of presenting signs they preferred, participants were most interested in learning vocabulary associated with children's stories. Finally, I deployed SMARTSign to parents for four weeks. Participants learning *Story* vocabulary used the application more often and had higher sign recognition scores than participants who learned vocabulary based on *Word Types*. The condition did not affect participants' ability to produce the signed vocabulary.

CHAPTER I

INTRODUCTION

In the United States, between 90 and 95% of deaf children are born to hearing parents [81]. In most circumstances, the birth of a deaf child is the first experience these parents have with American Sign Language (ASL) and the Deaf community. After diagnosis, these parents are faced with a number of difficult decisions including medical treatment options and communication methods. The majority of deaf children will use signing as a primary means of communication, and parents face challenges learning ASL as a second language both to provide their children with language models and to be able to communicate with their children more effectively. These parents must also embrace learning a language that is considered to be as difficult for English speakers to learn as Japanese [50].

Parents who decide to learn ASL are faced with many difficulties. Schools for the deaf frequently provide classes on evenings or weekends, but parents may live far away from the class locations and may not have the time or financial resources to devote to traveling to class. Time away from home can also be difficult to arrange for parents with young children. Books do not provide sufficient detail to help parents recreate the dynamic motion of signs from static images. DVDs can provide the detail of signs but require the learner to have access to a DVD player when they are ready to learn.

I propose a tool for helping parents learn and practice their ASL skills whenever free time is available using an application designed for a mobile device. Through my research I will demonstrate the feasibility of learning complex signs using a mobile device, develop an understanding of the unique issues faced by parents attempting to learn ASL and discover when and under what circumstances parents learning ASL

would choose to use a mobile language learning application.

Thesis statement: *Hearing parents of deaf children want to learn American Sign Language (ASL) for a number of reasons, but they are frequently unsuccessful. One common activity that hearing parents regret not experiencing with their deaf children is reading books together. Providing a method for parents to learn and practice ASL words associated with popular children's stories on their mobile phones will help improve their ASL ability. Parents who are given a vocabulary list designed for learning to sign stories will access the application more often which will lead to more exposure to ASL and more learned vocabulary than parents whose vocabulary list is designed around word themes.*

My thesis was evaluated through three studies. The first study focuses on determining whether or not novices are able to reproduce signs from the small screens of mobile devices. The ability to help individuals learn not only to recognize signs but also produce the signs is vital to helping them learn to sign. Previous work by Henderson-Summet has shown that people have been able to learn to recognize signs on mobile devices, but participants had difficulty reproducing the signs they learned [43]. The ability to reproduce signs will be critical for parents who are attempting to provide their children with a language model in ASL. My study took the form of a quantitative study with hearing individuals without prior experience in ASL. Chapter 3 describes the procedure and results from this first study in detail.

The second study takes the form of interviews with my target population, hearing parents with deaf children. The goal of these interviews was to identify a population of potential participants for future study, understand the difficulties parents experience related to actually learning ASL, and understand how a mobile language learning application might fit into their daily routine. Details of this study can be found in Chapter 4.

Based on the results of the first two formative studies, I developed the SMARTSign

application to help parents learn to recognize and produce ASL vocabulary. A detailed description of SMARTSign's features is given in Chapter 5. The final study involves a long-term deployment of SMARTSign to parents attempting to learn ASL. Details of this study can be found in Chapter 6.

The contributions of my dissertation will include the following:

1. An *in situ* study exploring the impact of a learning goal (reading a book or basic communication) on parents' ability to learn ASL vocabulary (Chapter 6).

2. An evaluation of novice signers' ability to reproduce signs displayed at varying resolutions on a mobile device (Chapter 3).

3. An interview study investigating parental motivations to learn ASL and current learning techniques (Chapter 4).

4. An analysis of how parents use a mobile learning application (Chapter 6).

CHAPTER II

BACKGROUND

In this chapter, I explore the literature relevant to helping hearing parents of deaf children learn ASL on mobile phones. This chapter begins with an exploration of deafness and ASL as a language. Research relevant to language acquisition is summarized in Section 2.2. Section 2.3 looks at the motivations for using mobile devices to facilitate learning. In Section 2.4 I look specifically at literature related to language learning on mobile devices. The chapter concludes with a summary of the tools currently available on mobile phones for ASL users.

2.1 Deafness

There are a number of social perspectives regarding deafness [90]. Frequently, deafness is defined merely as a disability related to the inability to hear sounds. To others, ASL is one aspect of the unique culture surrounding the Deaf community. This document will use "deaf" with a lower case 'd' to denote the medical diagnosis related to a hearing impairment. Deaf with a capital 'D' will be employed to indicate a reference to Deaf culture and the Deaf community.

Members of the Deaf community feel a strong connection to ASL and feel pride in being Deaf. During the late 19th century many prominent individuals in education feared the use of a sign language would prevent children from learning English [11]. This fear led to the rise of "oralism," suppressing the use of ASL in schools for the deaf in favor of purely oral methods such as lip reading and learning to speak English through mimicking its breathing and mouth shapes. Despite institutional efforts, ASL was still being passed from one deaf individual to the next in schools even under threat of punishment. This negative view of ASL remained prevalent until the 1960s and 70s.

It was only then that the practice of oral education was questioned. For approximately a century, a majority of deaf individuals struggled to learn exclusively spoken English. Only a few succeeded sufficiently to be productive members of society. As a result, many members of the Deaf community are vehement in their desire to protect their language and culture. Members of the Deaf community can be particularly strident regarding situations in which hearing individuals dictate policy for the Deaf. The desire for self-determination within the Deaf community reached a tipping point in 1988 when Gallaudet University, the university for the deaf and hard of hearing in Washington, D.C. was selecting a new president. Two candidates were deaf, and one was hearing. When the university governing board selected the hearing candidate, the campus community exploded in protest. Students, faculty, and alumni fought to have the decision overturned. After a week of protests and outreach to the media, the first Deaf president of Gallaudet was selected in what is called the *Deaf President Now* movement. For the first time, the Deaf community could dictate their own policy and showed their power as community. Old fears about the Hearing World dictating what is right for the Deaf World have risen again in the form of the debate over cochlear implants [3].

2.1.1 Growing Up Deaf

Parental involvement plays a large role in a deaf child's language development. Maternal communication in particular is a significant indicator of language development, early reading skills, and social-emotional development [18]. A large body of research has focused on language learning and development both for the population of hearing children and for deaf children learning ASL. Hearing children with hearing parents and deaf children with deaf parents develop their respective language skills at the same rate [100, 119]. Deaf children of hearing parents develop language in the same sequence as hearing children, and deaf children of deaf parents, but at a much slower

rate. This slower rate of development for deaf children of hearing parents has been attributed both to incomplete language models and less interaction [42, 105]. The target population for my proposed intervention are members of this third group: hearing parents who have deaf children.

For many years linguists were unsure whether ASL was a natural language. These attitudes changed through the work of Stokoe, a linguist at Gallaudet. Stokoe proved American Sign Language was a true natural language and helped validate the use of ASL as the primary language for deaf children [107].

2.1.2 Parental Decisions on Communication Methods

When parents receive the diagnosis that their child is deaf, they are faced with many decisions that must be made quickly regarding what communication method is best for the child. This decision is even more pressing because children who are deaf receive a confirmed diagnosis at an average age of 14.5 months [79]. The first three years of a child's life are critical for language acquisition. Additionally, early intervention services are typically only available to parents for the first three years of their child's life. The later a child is identified, the less likely they are to fully acquire any language [77]. More information about first language acquisition is given in Section 2.2.1. Fortunately this age of first identification is decreasing due to the implementation of universal screening tests for newborns in the United States [79].

The communication method hearing parents decide to use relies to a certain extent on the child's degree of hearing loss. For situations in which hearing loss is minimal they may prefer to use an oral communication method. If the child is a good candidate, parents may also have the option to provide their children with cochlear implants, which can improve a child's hearing capabilities, but physically destroys any residual hearing the child might still possess in the process. The high cost of cochlear implants and the follow-up therapy necessary to help the child adjust to

processing the signals they receive from the implants means that children who have better educated and more economically advantaged parents are more likely to receive implants [79]. When implants were first being performed, there was a large emphasis on using only oral methods of communication to encourage the children to use their hearing. According to the findings of Meadow-Orlans et al., about three-quarters of the mothers they interviewed and 65% of the fathers of children with cochlear implants report using some signs with their children, which is not significantly different from those whose children have not had implants [79].

A communication strategy that has become popular since the 1970s is Total Communication (TC) [65]. The philosophy behind TC is to provide the child with any and all possible methods of communication: ASL, spoken and written English, fingerspelling, and anything else which will help facilitate communication. This tactic might provide an advantage because parents give their children multiple communication tools without taking a side on the very political debate about what is the "proper" way to communicate. Children could also have the basis for a variety of communication methods and can choose the method which is most appropriate for the situation.

The age at which children with hearing mothers are first exposed to ASL varies based on the racial and ethnic background of their parents: White children have their first exposure at nine months on average, Hispanic children at 15 months, and African American children not until an average of 19 months [79]. This delay can be critical in determining the child's success in acquiring language skills.

The decision to learn ASL is not made lightly. Many parents experience fear at learning a new language. It can be very stressful to learn a new language and teach it to someone else at the same time. One parent described this process as "trying to teach somebody French when you don't know French yourself" [79]. Some parents also feel that it is inappropriate to ask their children how to sign something when

they do not know the sign themselves. Siblings can be another factor that makes the decision to use ASL more difficult. One mother interviewed by Meadow-Orlans et al. said her older son became frustrated because it took him longer to express himself in ASL than it did in English. It even made his younger brother impatient when it took him a long time to convey a story.

In general, the mother carries the majority of the burden of communication with the deaf child [79]. Many mothers reported that it took longer for fathers to adjust to the idea that their child was deaf. Another theory may be that fathers are more likely to be working and do not have time during the day to attend classes or practice, both of which are important for learning a new language. Mothers rate their ASL skills as the same or better than the father's 95% of the time [79].

2.1.3 American Sign Language

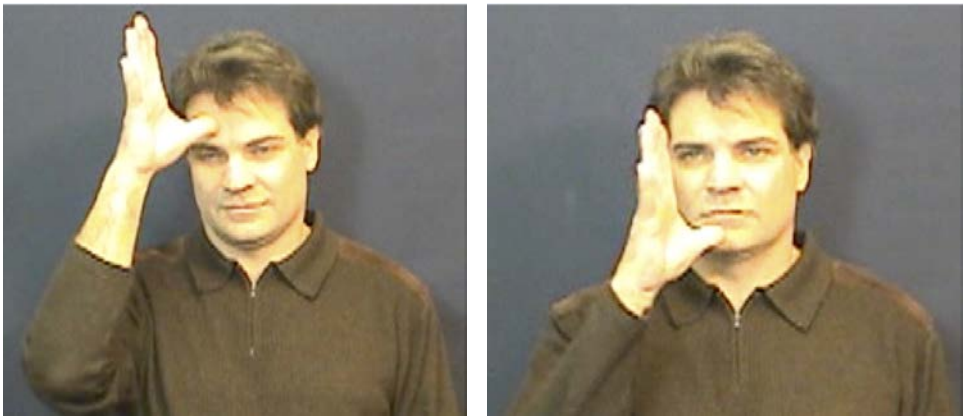
American Sign Language (ASL) is a natural signed language common to members of the Deaf community in North America. It is not simply English coded into a gestural system. ASL has its own linguistic structure unrelated to English and is a language in its own right [115]. In ASL, the handshape, movement, orientation, location on the body, and facial expression can all contribute to the meaning of a particular sign.

Although there are several research-based sign writing approaches, there is no well-established writing system for ASL [46]. In this dissertation, I use English glosses written in all capitalized letters to represent an ASL sign. Glossing is not meant to be a translation of the ASL into English, but instead a direct transcription of the ASL represented using English words. Figure 1 shows a phrase in ASL represented by pictures of the signs. A gloss of this phrase is "YESTERDAY I WORK I." The English translation is "I worked yesterday."

Some signs are easier to learn than others [43]. One reason may be because of how they are related in terms of their handshape, location, and motion. Figure 2 shows

Figure 1: A phrase in ASL - YESTERDAY I WORK I

three signs that are highly related to each other. FATHER, shown in Figure 2(a), and MOTHER, shown in Figure 2(b), are the same except for the hand's location on the body. GRANDMOTHER, shown in Figure 2(c), begins in the same location as MOTHER, but includes the motion of the hand away from the body. Remembering one sign may help learners remember the other related signs.



(a) FATHER (b) MOTHER

(c) GRANDMOTHER

Figure 2: Three related signs

Another explanation for why some signs are easier to learn may be related to the

iconicity of some signs. Iconicity, also known as transparency, refers to the characteristic of some signs to have a meaning clearly associated with the sign's performance. SCISSORS, shown in Figure 3, is an example of an iconic sign representing the action of the scissor blades. Sign language researchers disagree on the role that iconicity plays in a sign's learnability [67, 80, 89].

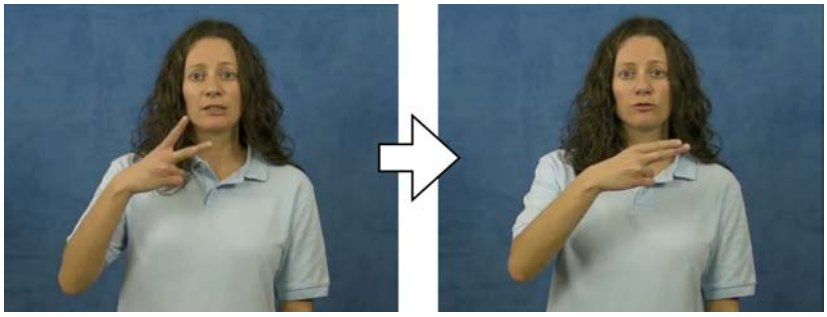


Figure 3: An iconic sign, SCISSORS

2.2 Language Learning

The goal of this research is to help hearing parents learn ASL so they, in turn, can provide language models for their children. As such, it is important to understand the issues related to both first language and second language acquisition. First language acquisition refers to going from a state of having no language, most usually as a baby, to being able to understand and communicate in a single language. The term second language acquisition then means that an individual already has mastery of one language, and they are in the process of learning a new language. The term second language acquisition is a misnomer, as it more accurately refers to any new language learned after the first, whether it is the second or the fourth. Second language acquisition theory is important to the development of SMARTSign because its goal is to teach ASL as a second language to hearing parents who already know English. Understanding of first language acquisition theory is also important because the ultimate goal of this project is that parents use their new-found skills with ASL to serve as a language model for their deaf children acquiring it as a first language.

2.2.1 ASL as a First Language

There is a high level of similarity in language development and early language acquisition in children around the world [68]. In the first three years of a child's life, language emerges and develops in fairly predictable patterns regardless of the language. This predictable development is contingent upon regular exposure to an accessible language. Deaf children of hearing parents frequently do not receive such exposure, which leads to significant language delays.

Children who experience delays in acquiring their first language are frequently less able to master the nuances of their first language and will also have more difficulty learning other languages throughout their lives [77]. Parental involvement plays a significant role in how well a deaf child born to hearing parents is able to learn language [82].

Mayberry has conducted many studies related to first and second language acquisition of deaf children [76, 77, 78]. The age of first language acquisition has a strong effect on how well that language is learned. It also has a small effect on the outcome of second language learning. That relationship is the same regardless of whether the first language is a spoken language or a signed language. One of the most important findings of her research is that delayed exposure to an accessible first language such as ASL results in an inability to acquire the necessary linguistic capabilities needed to acquire fluency in any subsequent languages [77]. The implication of these findings is the importance of parents learning ASL as early as possible. When parents do so, their deaf children can learn an accessible language to communicate and express themselves, and to provide a language base which will help the children learn English better.

There are a number of software projects that have sought to counter the negative effects of the lack of early first language development in deaf children. One such project, CopyCat, is aimed at helping children practice signing short phrases in a

video game environment to improve their working memory [13, 117]. A more ideal solution than trying to alleviate the language deficit is ensuring that there is no language deficit to begin with. The goal of the SMARTSign application is to help parents acquire ASL, a language more accessible to their children.

Parents do not explicitly set out to teach their children language in the same way that an adult would take a language class. Vygotsky observed that language learning for children is a social process [120]. Deaf parents are able to help their deaf children learn ASL in the same way that hearing parents teach their hearing children English [8]. Deaf parents of deaf children know how to provide the correct scaffolding for their deaf children, helping them to progress to the next level of their current language development. When a deaf child of Deaf parents is young, the parents know they should exaggerate their signs, which helps attract their child's attention and helps make the signs easier to understand. One skill lacking among hearing parents of deaf children, in contrast to Deaf parents, is how to manage the child's attention. A hearing parent with a hearing child will see the child's attention caught by something in the environment and speak about the focus of attention. This technique works because the language stream and the visual stimuli occupy different channels. For deaf children, language and visual stimuli occupy the same channel. Parents of deaf children then have to move around and adjust their signs so that the communication remains in the child's field of view. As their child gets older, Deaf parents use other techniques such as movement (waving) or tactile (shoulder touch) signals to indicate when their child should shift attention.

Parental language models do not need to be perfect. Singleton and Newport showed that deaf children with imperfect language models are still capable of developing an ASL ability that is actually of higher quality than their original models [102]. Hearing parents, due to their limited formal ASL training, might not feel comfortable using it for their everyday needs, and so they frequently find themselves only using

sign when directly addressing their deaf children [114]. However, children who are learning language rely on as much exposure to language as possible. Thus, one important key to improving language development for deaf children with hearing parents lies in helping parents be comfortable to use signs all of the time, even when they are not addressing their deaf child directly.

2.2.2 ASL as a Second Language

There are a number of tools available to aid people who are learning ASL as a second language, but few have been tested with any academic rigor [109]. Much of the current curricula are based on out-dated concepts of second language acquisition [97]. According to Rosen, some of the more popular teaching curricula are based on the "drill-and-kill" concepts of behaviorism, simply using repetition of the same concept to create memory associations. Current theories of language acquisition favor a more holistic approach in which the person is not simply learning language for the language's sake but instead to fulfill a purpose [15]. In this approach, learning should be organized around semantic themes and not the linguistic rules. While certain aspects of SMARTSign do still place value in repetition, the SMARTSign application can also be used for in-context learning and goal-directed exploration. For example, when parents search for a video of a sign for a word or concept they are trying to convey, they will immediately be able to use the sign in conversation.

Although a number of papers suggest the importance of hearing parents of deaf children learning ASL early and quickly [8, 77], there is little research that addresses the difficulties that parents face or provide methods for helping them learn faster.

2.2.3 Baby Sign

Baby Sign refers to the recent phenomenon of hearing parents learning signs to teach to their hearing children before the children acquire speech. There are numerous reasons put forth for why parents might want to use signing: to promote more explicit

communication (outside of simple pointing), minimize child frustration, improve development of spoken language, and improve parent-child bonding [93]. While any gestures could be used to foster communication, the advantage of using ASL as the basis of signs is that they will be more easily recognized by others since they come from an established language.

Baby Sign has a very short window of usage. Parents in one study typically started signing to their children between eight and 13 months of age [94]. During their second year of life (between one and two years old) was when peak signing activity occurred. After the children turned two and speech became more fluent, sign usage disappeared completely.

There is no concrete information about the number of families who use Baby Sign in the United States, but in one study of 14-month-old infants by Shield, 16 out of 28 infants had parents who reported using signs with their children [101]. This study does not necessarily mean that parents exposed their children to ASL or that they were learning ASL as a primary means of communication. A typical parent who incorporated signs taught their child between two and seven signs. The most common signs parents reported using were MORE, PLEASE, EAT, DRINK, THANK-YOU, and ALL-DONE.

Despite the recent increase of hearing parents teaching their hearing children signs through the Baby Sign movement, deaf children of hearing parents are still not receiving the language exposure needed to develop equally with their hearing peers. The difference between using a few simple signs temporarily and learning a complete sign language is large. While tips from the Baby Sign movement can be helpful in determining how to present new signs to parents, hearing parents with hearing children can still rely on their expertise with the oral/auditory channel to convey linguistic information, something that is not available to hearing parents with deaf children.

A few individuals in the Deaf community are in full support of the Baby Sign

movement despite the limitations. One Deaf university professor said that it might lead hearing parents to a better understanding of ASL and Deaf people [94]. The consequences may be more complex. Parents do frequently learn more about Deaf culture and ASL over the course of their signing. However, Pizer says that linking sign language to preverbal infants may reinforce the common misconception that ASL is a simpler language than spoken language.

There are some Baby Sign resources that could be useful to hearing parents of deaf children. In the Signing Smart system, the authors provide advice to parents on how to recognize a child's attempt at a sign [6]. Due to limited dexterity, an infant's early attempts at a particular sign will not completely resemble the "correct" form of the sign. Educating babies to use signs differs for hearing and deaf children. A parent with a hearing child can accept the child's form for a sign and reinforce the spoken word. It does not matter if the sign MORE is not produced correctly because the reinforcement of the spoken word "more" is more important in the end. A parent with a deaf child must continue to produce to correct signed form to reinforce the sign. The correct production of the sign MORE is the end goal.

Another domain where Baby Sign material could help hearing parents with deaf children is in helping children identify the connection between movements and meaning. Parents of hearing children encourage speech production by responding to their baby's random babbling. Similarly, deaf parents of deaf children respond to an ASL equivalent of baby talk. Anthony and Lindert provide advice to hearing parents, saying that responses to a child's meaningless movements can over time lead the child to realize that some movements can turn into meaningful or purposeful signs [6]. This behavior corresponds to the pattern of parents responding to babbling by mimicking. How best to adapt Baby Sign material for hearing parents with Deaf children is an area where further research is needed.

2.3 Mobile Devices

In this section I will describe the unique opportunities that arise due to implementation of a learning system on a mobile device. In the first section I discuss general advantages of mobile devices. In the second section I will discuss these advantages in terms of their impact on mobile learning.

2.3.1 Advantages

One advantage of mobile devices is that, due to portability, there is a higher likelihood of reaching a person more quickly than making a call to a land line or sending e-mail. It is important to be sensitive about how frequently contact with individual is made when developing for mobile technologies and communication [26]. Just because it is possible to contact an individual with some piece of information, does not necessarily always mean that the individual is open for interruptions. This consideration will be important in the design of any alerts that may be used by the system to notify the learners of new content or to remind them to spend some time studying.

Another advantage of mobile devices is the wide range of sensing abilities available. Modern mobile phones have accelerometers, GPS location, and microphones. All of these features could be used to help provide information to an application. There are a broad variety of applications currently available on the market that leverage these features. Mobile technology and infrastructure have only made mobile learning feasible since around 2005 [63].

Personal ownership is another advantage of mobile devices [61]. Laptops or desktop computers are more likely to be shared resources, due to their cost. In contrast, a mobile phone is a personal device. Individual ownership of a device results in different patterns of use than with a shared device. When deploying a study on mobile devices, patterns of use will not be the same on a borrowed device as on an already-owned device or a device that has become personalized.

2.3.2 Learning

Many mobile learning research projects are still in the conceptual phase of discussing what learning looks like on a mobile device and not necessarily evaluating the efficacy of the technology intervention [12, 45, 62, 71, 122]. Modern constructivist theories of learning involve project-based, exploratory, and situated learning. Holzinger et al. suggest these theories can be implemented on a mobile phone. They also posit that the key to mobile learning is understanding that the learner is more likely to learn in small chunks and allowing the easy resumption of learning from previous activities. There is one important caveat to the use of exploratory learning: novices can become lost without a clear or guided learning path. Therefore, individual exploratory learning might be better suited to more expert learners.

Another area of research for mobile learning focuses on design considerations for devices with limited screen sizes [71]. Luchini et al. describe a learner-centered design project that allows the creation of concept maps on a handheld device. One of the components of learner-centered design is the necessity of scaffolding and its ability to fade over time. Scaffolding is specific support for the learner which helps them reach the next level of understanding on a topic. With limited screen space, there can be difficulties with both maintaining scaffolding and providing users with a manageable amount of information. The authors suggested dividing the learning task into smaller pieces and displaying them on a progression of screens. This division enabled them to tightly couple the tools necessary to create the concept map with the scaffolding. The resulting trade-off was that the overall context from the learner's activity was sometimes lost due to switching between an overall map view screen and an editing screen to create concepts within the application.

Bomsdorf envisioned features of a learning system that could incorporate ubiquitous computing principles focusing mainly on the concept of adaptation [12]. She

enumerated four different ways that ubiquitous learning could use adaptation to provide useful learning activities in a variety of contexts. These four methods are:

- **content filtering** - changing the complexity of information based on the level of engagement expected by the user.
- **application filtering** - the concept that the same content should be presented in different forms depending on the learning method.
- **polymorphic presentation** - providing content with differing levels of detail.
- **content ranking** - using content and application filtering to provide a list of activities from which a user can choose.

If the learner is on a mobile phone in a crowded environment, it is not desirable to present complex information. However, providing varying levels of detail allows learners to access more information when they have more time available. Presenting material in a variety of ways will help retention. A mobile learning system must be flexible enough to allow the learner to always be able to choose an activity that can help them learn.

Kukulska-Hulme created a taxonomy of mobile learning activities [62]. The main motivation of this taxonomy was the realization that researchers and teachers can develop tasks, but learners will appropriate them in unexpected ways. We cannot predefine where mobile devices will be used, how they are integrated into an individual's learning process or how the technology will be used. Previous paradigms of use that focused on the teacher will not be valid for activities on a mobile phone. She proposed three models:

- **specified activity model** - Learning material is packaged and delivered on mobile devices. The activities are specified and learners are expected to carry them out. These activities could be inside a scheduled class, but they could continue outside classes as well.

- **proposed activity model** - A task that is helpful to learners, but it is not mandatory that they perform it. It is left to the learner to find the materials and use them as they wish.
- **learner-driven activity model** - A learner-driven activity is self-initiated. Learners use their devices to learn spontaneously, downloading podcasts or communicating with their teacher or peers.

One interesting thing about this taxonomy is that although it was developed for mobile learning, it is still focused on using a course curriculum as a central component.

Most mobile learning research focuses on integrating mobile learning in the classroom which could be the motivation for the classroom focus in Kukulska-Hulme's taxonomy. Where would an application not associated with a class fit in this taxonomy? It seems most likely that such an application would be a **proposed activity** using this taxonomy. Activities in a mobile application would be helpful, but how they are used would be entirely at the learner's discretion. How can an application be designed for the learner-driven activity model? I believe that such an application would not explicitly deliver content according to a static curriculum, but instead would provide a mechanism for learners to both to collect words and content they acquire from other sources, and allow them to share and discuss their collection with others.

When designing technology, it is important to be aware of the seams [10]. Like the seam on a shirt, a seam in technology is a point where two distinct parts are connected in some way. A seam could be a result of technological limitations, for example the limited broadcast area of wireless access points or cellular towers. It could also be the transition between two activities, such as interrupting a game of Solitaire on a smartphone to answer a phone call. Wong and Looi explored the seams that could arise in mobile learning [122]. Some of the seams are based on aspects of learning pedagogy: formal versus informal learning, acquisition versus synthesis

of knowledge, and accommodating multiple pedagogical or learning activity models. Others are based on the technology: personalized versus social learning, varying times and locations, designing for multiple device types, and switching between the physical and digital world. The final seam, switching between learning tasks, could be either technological or pedagogical. The system should support task switching and the tasks should flow well together in a coherent pedagogical progression.

Although Wong and Looi propose designing to remove all seams, designing a successful mobile learning technology should not be incumbent upon removing all possible seams. It is important to consider each seam's impact on the learner and make accommodations in the design to remove the seams that could make learning more difficult or inconvenient. Alternatively, the designer should change the nature of the tasks so that the seams do not impede successful performance. Barkhuus et al. showed that seams do not need to be a detriment, but can be turned successfully into a feature when they made the limitations of wireless network access integral to their mobile game [10].

2.4 Mobile Device Mediated Language Learning

In the past five years, with the increasing prevalence of smartphones, the number of research projects using mobile language learning has increased. A table summarizing relevant mobile language learning projects is shown in Appendix A. While most projects and studies have focused on university students, other research has included schoolchildren and adults. Some research projects support learners already living in the target language environment, and other research projects support learners living in their native language environment learning a foreign language. Most research focuses on learners who are taking classes and thus must complete assignments for grades. Self-paced use of mobile language learning outside of class requirements is under-explored. In this section I will discuss the trends in mobile language learning

and their relevance to my current research.

2.4.1 Topics in Mobile Language Learning Research

The most common approach when employing mobile phones to teach a language is to use the mobile phone for studying what are essentially digital flashcards [2, 20, 30, 29, 70, 99]. The goal of this type of research is perfecting an algorithm to determine what vocabulary should be presented, what time during the day it should be studied, and how often. Some of these systems focus on context-awareness (location, time, or other factors) to provide lessons at moments when they should be most useful to the learner [2, 24, 30]. However when users of learning applications were surveyed, the availability of contextually relevant content was not a significant factor in determining long-term usage of an application [91]. Presentation algorithms can lead to improvement in the amount of vocabulary learned [20], but the improvements might not be long term [70]. One failure with these algorithms is that they introduce new vocabulary without providing the learners with sufficient opportunities to review previously learned vocabulary [20, 29].

Phones are popular platforms for learning tools in developing countries and for immigrant populations in developed countries due to financial reasons [51, 92, 95]. Mobile phones are cheaper and have greater market penetration than computers in developing nations. Schoolchildren in India played a Boggle® clone with their classmates on mobile phones to practice their English [51]. The researchers used mobile phones and pico projectors because of their lower cost and lower energy requirement in comparison with providing a computer to every child or using a SMART Board®. The children were able to improve their vocabulary when playing, both with a single shared display and with each phone serving as a personal display.

In another project, Bangladeshi women living in London were given mobile phones with access to English learning tools for ten weeks [95]. The women's confidence in

understanding, reading, speaking, and writing English improved over the course of the study for both those enrolled in formal classes and those who used the mobile phone as their primary method of learning. Many of the women who were not in a formal class during the course of the study subsequently enrolled in classes, indicating that mobile language learning tools can serve as a gateway to encourage novice learners to seek further sources of language practice.

Researchers have also incorporated games into mobile language learning tools [28, 33, 96]. The game MOBO City was designed for mobile phones because it was intended for use in a developing country. In developing countries mobile device ownership is common, but laptops and desktop computers are rarer [33]. The game took a different approach to language learning by focusing on teaching a subject relevant to the audience, motherboard components, with the aim of improving language skills. Participants who played the game reported that they found the game engaging. These participants also demonstrated more comprehension of the related vocabulary when compared to participants who only attempted reading comprehension of the vocabulary with or without a dictionary.

The mobile game Tip Tap Tones, was designed to help learners of Mandarin Chinese living in China practice tone recognition [28]. In tonal languages such as Mandarin, the meaning of a sound can be determined by its pitch (or changing pitch) and context of use. Differentiating between different tones is very difficult for non-native speakers. In Tip Tap Tones, learners would hear a Mandarin sound and were asked to tap a button corresponding to the correct tonal representation. They were rewarded for accuracy and speed. After playing the game over three weeks, participants were able to improve their tone accuracy for both tones and syllables that were trained in the game and those that were not trained by the game. Post interview studies showed participants felt that rising scores and time pressure made the game addictive.

The AMICITIAS project is a series of games designed to be played in specific geographic locations. The games teach language skills through learning about the particular location and interacting with people who live or work there [96]. Versions have been built for a number of different locations in Europe. The AMICITIAS project is unique in that it teaches both the primary language as well as a secondary minority language that is spoken in the location. For example, in Toledo, Spain, learners interact with the game in Spanish, but they also learn some Arabic, a minority language for the area. To complete tasks in the game, learners need to interact with locals and visit museums and landmarks to answer questions posed by the game.

The researchers found that rather than following the task set out by the game explicitly, participants took shortcuts to some of the tasks that led to longer and more meaningful language exposure than expected. One example of a shortcut was a task that involved visiting historically important pubs in Galway. The students asked the staff in one of the pubs to help them with answering all of the questions in the game instead of visiting each location individually. The staff did not know all of the answers, but they did teach them some Gaelic words. Then the pub staff started asking the kitchen staff. The chef came out, answered more questions and then directed them to a historian friend who lived in the area. While the group did not carry out the task as originally intended, they were able to interact with more people and get more exposure to the target languages. When learning tools are provided for use outside the controlled environment of the lab or classroom, learners may use them in interesting ways that can expand learning opportunities.

Many of the studies described above took learning material that could have been provided in another way, via flash cards or computers, and presented them in a similar format on a mobile phone. In contrast, there have been a number of projects that use the mobile nature of the phone, its cameras, or the communication and location capabilities in creative ways [21, 39, 58, 88, 121]. In one project involving a trip to

the zoo in Taiwan, students used mobile phones to listen to relevant audio content in English [21]. Students with lower English proficiency benefited from accompanying text, while for those with higher ability, audio alone reduced the cognitive load. The language skills of the student determined whether a multimodal or a single mode presentation was most beneficial. Another tool that involved students interacting with their environment instead of in a classroom was designed for foreign students at a university in Japan. This project allowed teachers to track the students' GPS location while they were performing specific tasks in the area [88]. The teacher would assign a task such as going to a local supermarket to buy and learn about a local delicacy. The student would activate the system so the teacher could provide assistance if the student became lost or needed help with communication. This tool could be beneficial for new students to the area who are not comfortable with basic communication in the native language.

In her survey of mobile language learning projects, Kukulska-Hulme noticed that although mobile devices are primarily communication devices, very few research projects support interaction between learners [60]. Additionally, mobile phones are also intended for voice communication, but there are few projects that involve voice. One project that intended to use voice communication experienced difficulty with getting participants' schedules to coincide [60]. Incorporating synchronous communication in a mobile language learning project does reduce the possibility of spontaneous self-initiated learning opportunities because the learner must rely on another individual to complete a learning activity.

The camera and video recorder have become ubiquitous on modern mobile phones and can also be used for language learning [39, 58, 121]. Wong and Looi designed a system for elementary-aged children in China, both native and non-native Chinese speakers. The students used the camera on mobile phones to take pictures throughout the week and make stories that would practice Chinese idioms [121]. Because the

phones were with them all of the time, it led to more opportunistic associations when children would see something during their daily lives that could connect well with an idiom they were learning in school. There were also instances when the children found that a picture they had taken randomly could then be applied to an idiom. Both of these situations allowed the children to make associations between the things they were learning in school and their everyday life.

Another system proposed that language learners could use the camera to take pictures of words or phrases that the students did not understand [58]. The phone could then use OCR to retrieve the text from the image. That text would then be processed by Google Translate to provide a preliminary translation. The original image and the corresponding translation would then be shared on the cloud for the benefit of other learners. Other members of the community could also revise translations for greater accuracy. This type of system is not yet feasible for ASL because our ASL recognition and translation capabilities are not at the same level as text recognition and translation. In another study, engineering undergraduate students in Japan were asked to record 30-second videos in English weekly in a 14-week class [39]. Their videos were shared with the entire class. The students liked seeing other's speaking styles, but some felt self-conscious about their own abilities. Similarly, my research shows that parents learning ASL report feeling self-conscious or embarrassed when signing [116]. While peer feedback and exposure to more signed material might be beneficial, it could also be a barrier to using a system in the first place.

A number of research studies investigate how to provide material to students on their mobile phones via Short Message Service (SMS) [55, 66, 108]. These studies leverage the fact that students are more likely to be accessible on their mobile phones, and thus can be provided with more study opportunities throughout the day. Thornton and Houser designed a system for students in Japan learning English [108]. Their main finding was that students do not start a lesson immediately upon receipt

of a notification. Instead, the students would wait until they had free time to look at the lessons. One common time for viewing a lesson was during their commute home. Students who received the messages did learn better (based on pre- and post-tests) than students who were only reminded to study once a week during class. Thornton and Houser also found that it did not matter whether short or long messages were sent. Repetition of learning content was most important.

Unlike other studies that focus mainly on vocabulary instruction, Kennedy and Levy also provided four other kinds of SMS messages: Italian life and culture, course announcements, TV programs of interest, and outside class activities [55]. While the reactions to the messages and their variety were positive, half of the students reported reading them regularly. Around 43 percent would save the messages to review. Even though replies were not required or encouraged, around one-third of the students sent one or more replies to the system. No evaluation of the SMS's impact on learning was made in this study. They initially sent two messages a day but reduced the frequency halfway through the study after a poll showed that students preferred fewer messages. In total, 55 messages were sent out over 7 weeks.

Li et al. critiqued systems which did not take advantage of the "anytime, anywhere" aspect of mobile phones [66]. Most SMS language learning systems are based on a "push" paradigm for lesson delivery. The system sends messages out to the learners at specified times during the day. Li et al. believed that the "push" paradigm reduced the opportunities learners had to study. Learners could not request new lessons when they had free time, also known as "'pull" lessons. Li et al. proposed a system for studying Japanese kanji which allowed both "push" and "pull" lessons. The system was adaptive to user interests and language ability. They also designed the alert system to be adaptive and alter the alert time based on the user's response history. This adaptation was designed to find each learner's individual ideal notification period. They tested the system over a one month period. One group of learners

received alerts at fixed times, and the other group received the adaptive alerts. While the dynamic alert group did have better post-test scores than the fixed alert group, these results were most likely not significant. The scores were relatively high in both groups on the pre-test and post-test. While the system was designed to accommodate both "push" and "pull" lessons, the study did not provide insight into the trade-offs between the two.

The systems described above were created to supplement class curricula. SMARTSign was designed without the support of a classroom structure. This difference could impact parents' willingness to receive alerts positively or negatively. Parents might want to receive more alerts because they do not have regular classes to enforce learning. Alternatively, they might not want to be interrupted at regular intervals because they need to focus on their family and work responsibilities. The role of notifications in SMARTSign is one potential area for investigation.

2.4.2 Adult Learners

Studies of adult language learners can provide insight into how best to help parents learning ASL [4, 28, 29, 30, 40, 72, 84, 86, 92]. An early study by Ally et al. involving adult English as a Second Language (ESL) learners in Canada showed that the participants liked the ability to access their learning content anywhere and did show a slight improvement in their abilities over time through using the mobile phone. When given the option of multiple choice, true/false, matching, and word ordering questions on mobile devices, the participants liked quick response questions such as multiple choice and true/false. They felt that the screen size did not adequately support matching and word ordering tasks. These results may not hold true for learning material on smartphones due to better interaction paradigms and more screen space.

Office workers in Shanghai were asked to test a mobile phone application that taught English phrases that might be useful for an upcoming world exposition in

the city [40]. Although it was a single session lab study, participants were pleased with the practical nature of the content and the design of short learning units which could be completed in less than two minutes. For busy adults it is crucial to focus on content and tasks that are important to them and design learning activities that are short or interruptible. As mentioned earlier, in her study of Bangladeshi immigrants in London, Pearson showed that mobile language learning content can inspire adults to pursue more formal classes [92].

Experiential learning is the learning that occurs over the course of one's everyday life as opposed to learning that occurs through a formal curriculum. ALEX is a project designed to help functionally illiterate adults using the paradigm of experiential learning [72, 84]. When designing the system, the researchers focused on working with the target population to discover the problems they faced while interacting in the world and created mobile solutions to help alleviate those problems and create learning opportunities. This method is also well-suited to the development of SMARTSign. When using ALEX, participants started to form a relationship with the device, and also showed it off to their friends and family [84].

Though not a study of mobile language learning, Nielson studied adults who were given the opportunity to learn a language at work using commercial desktop software [86]. The participants in the first study were employees of the United States government who choose to learn Spanish, Arabic or Chinese. In the second study the participants were employees of the U.S. Coast Guard who were learning Spanish. Nielson found that learner retention was the biggest challenge. In the two studies, 51% and 41% of the participants never even logged into their accounts. Only one out of 150 participants in the first study and four out of 176 participants in a second study completed an entire 20 week course. Much of the attrition rate can be explained by some agencies' reluctance in allowing participants to install software on their work computers and in allowing them to use the microphones necessary to properly use

the learning material. The software itself also provided frustration. In the first study, participants who used Rosetta Stone to learn Arabic and Chinese found it difficult to learn the script without extra instruction, indicating that languages that are significantly different from English may need different types of support than Romance or Germanic languages. Providing the proper support will also be crucial for parents learning ASL, a visual rather than spoken language with a spatial grammar.

Edge has done the most promising research on adults who are learning foreign languages on mobile devices without benefit of regular coursework [28, 29, 30]. In addition to TipTapTones, discussed in the previous section, there are two additional projects, MicroMandarin [30] and MemReflex [29]. All of these projects are designed to help the expatriate community in China learn Mandarin Chinese. In a formative study of Chinese and English learners in Beijing and Seattle, Edge found that learners' satisfaction with learning the language was not based on the target language or where the learning happened. Instead, satisfaction was based on whether they needed the language they were learning to accomplish goals such as work or school and if they had a supportive relationship with one or more native speakers [30]. The learners who were least satisfied were those who studied a language but could not practice it with supportive native speakers and studied the language because they lived in the country, not because they needed it for work. They reported high levels of "frustration, embarrassment, and panic" when trying to use the language with native speakers. However, after a study session, participants did report feeling more confident to take the risk of speaking to a native.

Parents learning ASL to communicate with their deaf children face many of the same frustrations of expatriates living in a country speaking a different language. However, hearing parents usually have even less daily interaction with a native ASL signer. Their children are not strong communication partners when they are young

and can be very critical of their parents signs as they get older [116]. Unlike expatriates who cannot avoid interaction with speakers of their target language, hearing parents with deaf children have few opportunities for ASL exposure.

One key finding from the final MemReflex study was letting the user have control over their study pace because of varying needs over time and users. Participants did not like feeling like they would never catch up if they missed a day. The authors also make the opposite point that when designing a system, learners need to be made aware that not studying leads to forgetting. In the study, participants used a flashcard application for three weeks using two different presentation algorithms [29]. There is no data on times accessed per day and the regularity of that access. Participants were asked to do 20 repetitions (one session) per weekday for each algorithm resulting in 300 total repetitions per algorithm over the course of three weeks. The participant who used the application the most did 740 repetitions per algorithm, and the participant who studied the least did 160. Only three of the 12 participants studied below the minimum requirement.

2.5 Existing ASL Tools on Mobile Devices

The efficacy of ASL learning on mobile phones is relatively unexplored with the exception of the work of Henderson-Summet. Henderson-Summet lay the groundwork for the current implementation of the SMARTSign application [43]. Henderson-Summet found that people could learn to recognize more ASL vocabulary when using a mobile phone than when using a computer. Post-study language evaluations showed that learners had difficulty remembering how to reproduce the signs they had studied and learned to recognize. Nadalutti et al. developed an ASL generation system using avatars and suggested that their work could be used for mobile language learning systems [85]. However, a mobile language learning system was not implemented.

There have been a number of mobile applications created for the Deaf community.

These projects include aiding communication between deaf and hearing individuals [17], helping Deaf individuals communicate with each other through video chat [19, 22, 57, 110, 111], and enabling deaf individuals to navigate the hearing world through text-to-sign language translators [41]. Al Ameiri et al. designed a system to help deaf individuals translate Arabic text to Arabic Sign Language and to convert Arabic Sign Language to text using a fingerspelling keyboard to ease communication [1]. The authors say it could be used to learn but do not explicitly design for learning.

With the advent of the iOS and Android application development SDKs, a number of dictionaries and learning applications are available for mobile phones. None of the existing applications have been evaluated for learning effects. These applications focus on learning individual signs via avatars or illustrations. While some applications incorporate a flash card paradigm, most consist of only a dictionary without type-to-search functionality. Free versions have very limited vocabulary sets.

2.6 Theoretical Motivation for SMARTSign

Learning signs by the current methods may not allow for optimal success [34]. A description of these methods and their problems will be discussed in Chapter 4. A large number of parents are learning some sign, even though their learning is hindered by inefficient methods and media [79]. However, they are not learning enough to be fluent signers, as evidenced by the lack of language skills exhibited by most deaf children of hearing parents [53, 103, 104].

The reasons for this low fluency may be related to the traditional means for learning sign language. Our early formative studies on SMARTSign found that many parents who wanted to learn sign language had difficulty using current resources. A major limitation for learning sign language is time. Parents reported having little time or energy to learn from a sign language book or watch a sign video after a full day of work and home life. Another major obstacle is convenience. Parents expressed

their frustration with difficulties they had attending sign language classes. Typically they had to drive long distances, usually on a weekday night after work, to attend a two-hour class. The rigors of family life overcame their desire to attend class on a regular basis. The goal of SMARTSign is to provide learning opportunities for parents which make a minimal time demand yet still improve their success rates for language acquisition and mastery.

How do we determine when learning should occur? Research has shown that studying material a few times over a long period of time, or distributed practice, is better than repeatedly studying in a short period of time, or massed practice. Ebbinghaus first noted this phenomenon, known as the spacing effect, in 1885 [27]. The spacing effect has been the subject of many published studies [16]. Baddeley [7] summarizes this finding with the statement, "As far as learning is concerned, 'little and often' is an excellent precept." Henderson-Summet explored the effects of distributed versus massed practice on individuals learning ASL on mobile phones and on personal computers [43]. Her research showed that the correct spacing for study sessions is still an area for further exploration. As discussed in Section 2.4.1, mobile phones can take advantage of both "push" and "pull" opportunities for learning. The components of SMARTSign have been designed to accommodate either paradigm.

Early iterations of SMARTSign have used Monitor Theory [59] to guide its formulation. For second language learning, Monitor Theory hypothesizes that adults have two independent systems for developing ability in second languages: subconscious language acquisition and conscious language learning. Subconscious language acquisition is very similar to the process children use in acquiring first languages as described in Section 2.2.1. Meaningful interaction in the target language is required. However, meaningful interaction in ASL can be difficult for hearing parents with deaf children. They usually do not feel comfortable interacting with adult members of the Deaf community [116]. In contrast, conscious language learning is the result of formal

instruction [59]. In designing SMARTSign, we hope that the formal instruction we provide will increase parents' confidence in their sign language ability. Once their confidence is increased, parents will be able to make the transition and feel more comfortable seeking opportunities for subconscious learning.

Retention of a new word or concept depends on the quality and frequency of the learning activities [48]. Over time and with enough exposure, word recognition will become relatively automatic [36]. Words should be encountered in speaking, reading, writing, and listening tasks and then deliberately practiced to facilitate a lasting memory [48]. ASL does not have a written form. However, parents must be exposed to both signing (production) and observation of signs (recognition). SMARTSign allows for immediate *in situ* learning. The application provides opportunities for learning in a manner that fosters ease of use and access to ASL vocabulary in a manner that is not available via books, video, or class attendance [116].

The current version of SMARTSign concentrates on vocabulary acquisition. While vocabulary knowledge alone does not constitute fluency in ASL, knowledge of vocabulary is a crucial first step for many parents who wish to communicate with their deaf children. Marchman and Bates have shown that an approximately 150-word vocabulary is sufficient to increase the rate at which new words and grammatical skills are acquired [73]. Child development research, discussed in Section 2.2.1, has shown that some level of ASL exposure for deaf children is vastly superior to no language exposure [102]. Even exposure to "survival level" signing can benefit children and is a worthwhile endeavor for families with deaf children.

SMARTSign provides the opportunity for more conscious language learning via formal instruction on a mobile phone. Gradual acquisition of knowledge is expected as the novice (hearing adult) learns from the expert. The adult then becomes the expert for the younger novice (deaf child) who gradually acquires the knowledge as well. Thus, the design of SMARTSign provides support and instruction to allow

for efficient acquisition and learning of vocabulary which is a necessary part of any language.

CHAPTER III

VIDEO STUDY

3.1 Introduction

In this chapter I describe my first study designed to determine whether video size is a barrier to a person's ability to recreate signs viewed on a mobile device. The goal of the study is to determine the appropriate video resolution needed to present new signs to novice ASL learners. A secondary goal is to assess the benefits, if any, of including more detailed information about handshapes in the signed videos.

The motivation behind the video study is to determine whether mobile phones are capable of displaying ASL videos in sufficient detail to allow novice signers to reproduce the signs. Henderson-Summet demonstrated in her thesis work that it is possible for novices to learn to recognize signs from mobile devices. Participants correctly provided the English glosses for signs when prompted with a video of the sign [43]. However, she found that people had difficultly producing signs when prompted with the English gloss.

There are two likely factors which could have caused this difficulty with sign production. One potential factor is the mismatch between tasks employed during the learning and testing phases. During the learning phase, participants were asked to watch videos of signs and provide the gloss. They were not informed that they would be required to perform the signs during the testing phase. This mismatch may have

Portions of this chapter are excerpted from Kimberly Weaver, Thad Starner, and Harley Hamilton "An evaluation of video intelligibility for novice American Sign Language learners on a mobile device," in the proceedings of ASSETS, 2010 [118]

led to the difficulty participants experienced in the generative portion of the testing session. A second potential explanation for poor generative test scores is that the mobile device screen may have been too small for people to be able to observe the details necessary to recreate a sign.

3.2 Related Work

Although many groups are working on developing signing avatars to help the Deaf community for a variety of sign languages [31, 41, 38], few projects include evaluations of sign intelligibility. Glauert et al. investigated the intelligibility of signs from signing avatars in the VANESSA system. They found that only about 60% of the avatar's phrases were recognized successfully by the Deaf participants [37]. These experiments are typically trying to test the limits of the system by deliberately making the test difficult. Improvements for signing avatar systems are being developed which can improve sign comprehension [47]. However, these avatar projects focus on fluent signers, not the novice signers who are the targets of our research.

There are a few instances of employing either signing avatars or video for educating novice signers. Karpouzis et al. incorporated animations of virtual characters performing Greek Sign Language into an educational system for Greek elementary school students [54]. No evaluation was performed to compare comprehension of signs from signing avatars against comprehension of signs from other sources. Sagawa and Takeuchi investigated an avatar-based teaching system designed to help novice signers learn Japanese Sign Language [98]. Their system used avatars in two ways: as an exemplar of what the person should sign and as a reflection tool showing learners what they actually signed. Participants viewed the avatars simultaneously performing the exemplar and their own sign to help with self evaluation. Around half of the participants responded positively to the intelligibility of animations. This paper did not report measures of the participants' actual sign performance. Johnson and

Caird [52] investigated the effect of frame rate and video presentation (normal versus point light video) on novices' ability to match signs with their English equivalent. There was no effect of frame rate, but there was an effect of video presentation. This study focused on impact of video quality on the recognition of signs and not on the production of signs which is the focus of my study.

Research investigating video intelligibility of ASL on mobile devices focuses on video quality for ASL experts conversing using video chat applications [19, 23]. Ciaramello and Hemami created a metric for predicting the intelligibility of compressed video based on fluent signers' gaze patterns when observing signs [23]. Cavender et al. evaluated video intelligibility by manipulating video compression parameters for conversational signing with fluent signers on mobile devices [19]. They were studying conversations that needed to occur in real-time; therefore, their focus was on finding the appropriate encoding settings for capturing signed video on a mobile device and transmitting it over a network with limited bandwidth. In contrast, the SMARTSign application can store videos directly on the mobile device. Thus, the application has more freedom to deploy videos at higher frame rates and at larger sizes. Both Cavender et al. and Ciaramello and Hemami could leverage knowledge about how fluent Deaf signers perceive signs in their design approach [83]. For the SMARTSign application, it is necessary to ensure that videos provide sufficient detail for novice signers to learn nuanced facial expressions and complex handshapes from them in order to reproduce the signs and not just recognize them.

3.3 Evaluating Video Intelligibility

In this section I describe the vocabulary selected for the study, how videos were generated, and the method used to determine an appropriate resolution for presenting ASL videos to novices on a mobile device.

Figure 4: The Motorola DROID as used to display signed video in the experiment

3.3.1 Vocabulary Selection

A vocabulary of 80 signs was selected for the study. These signs are the exact signs used by Henderson-Summet, and the same videos were employed [43]. The vocabulary was a subset of the MacArthur-Bates Communicative Development Inventory (MCDI) [32]. The inventory is used by parents to track the language development of their children and was originally developed for English. The vocabulary tracked in the inventory is commonly used by parents and children between birth and 35 months. The MacArthur-Bates inventory has been validated in many languages besides English, including ASL [5]. Table 1 lists the 80 signs grouped by category. When choosing which signs to include in the study, emphasis was placed on signs that could be used by very young children but could still allow more complex phrases to be created from them as the children develop.

3.3.2 Video Creation and Presentation

I created four video presentation conditions to be displayed on a Motorola DROID mobile phone running the Android 2.1 operating system (Figure 4). The native resolution of the Motorola DROID is 854x480. The signer in the videos is a hearing

Table 1: Vocabulary by category

Adjectives			
BAD	BIG	CAREFUL	COLD
GOOD	HAPPY	HOT	HUNGRY
LITTLE	SICK	THIRSTY	TIRED
Animals			
CAT	DOG		
Clothing			
JACKET	PANTS	SHOES	
Food			
APPLE	BANANA	FOOD	JUICE
MILK	SWEET		
House			
BATHROOM	BEDROOM	HOME	
Locations			
SCHOOL			
Nouns			
BOOK	MEDICINE	SOAP	TOY
WATER			
People			
BABY	BROTHER	DAD	GRANDPA
GRANDMA	MOM	PERSON	SISTER
Prepositions			
DOWN	IN	OFF	ON
OUT	UP		
Pronouns			
I	MY	THAT	THERE
THIS	YOU	YOUR	
Question Signs			
WHAT	WHERE	WHO	
Routines			
HELLO	MORE	NO	NOT
PLEASE	THANK-YOU	YES	
Times			
NOW	TOMORROW	YESTERDAY	
Transportation			
CAR	TRUCK		
Verbs			
DRINK	EAT	FINISH	GO
HELP	HURRY	LOOK	LOVE
SLEEP	STOP	WAIT	WANT

(a) High resolution

(b) Medium resolution

(c) Low resolution

(d) High resolution + inset

Figure 5: Four video conditions for the sign WHO

individual who is fluent in ASL. He has 20 years of ASL experience and interprets regularly. All videos used in the study were recorded with the same location, lighting conditions, background, and clothing. The signer wore a dark shirt to contrast his skin so that his hands and face would be more easily discernible. All videos were encoded using the H.264 codec. The average duration of the videos was 3.18s ($SD = 0.45s$) and the video frame rate was 25 fps.

The four conditions can be seen in Figure 5. Three of the conditions involved the manipulation of video resolution resulting in high, medium, and low resolution conditions. In the highest resolution condition, a 640x480 pixel video was shown. The high resolution video can be seen in Figure 5(a). 640x480 is the highest resolution

the mobile device is capable of displaying with the current video's aspect ratio of 4:3. The resolution was halved for the medium condition resulting in a 320x240 pixel video, shown in Figure 5(b). The low resolution condition halved the resolution again, resulting in a 160x120 pixel video, seen in Figure 5(c). The average file size of a high resolution video was approximately 340 KB. The average file size of a low resolution video was approximately 129 KB. In all three of the resolution manipulation conditions, the video was stretched so that, in every resolution, the videos appeared to fill the same physical screen size as the high resolution video (i.e., 60 mm wide by 45 mm high). The final experimental condition involved adding zoomed-in views of the handshapes to the high resolution video. This inset condition is shown in Figure 5(d).

3.3.3 Experimental Method

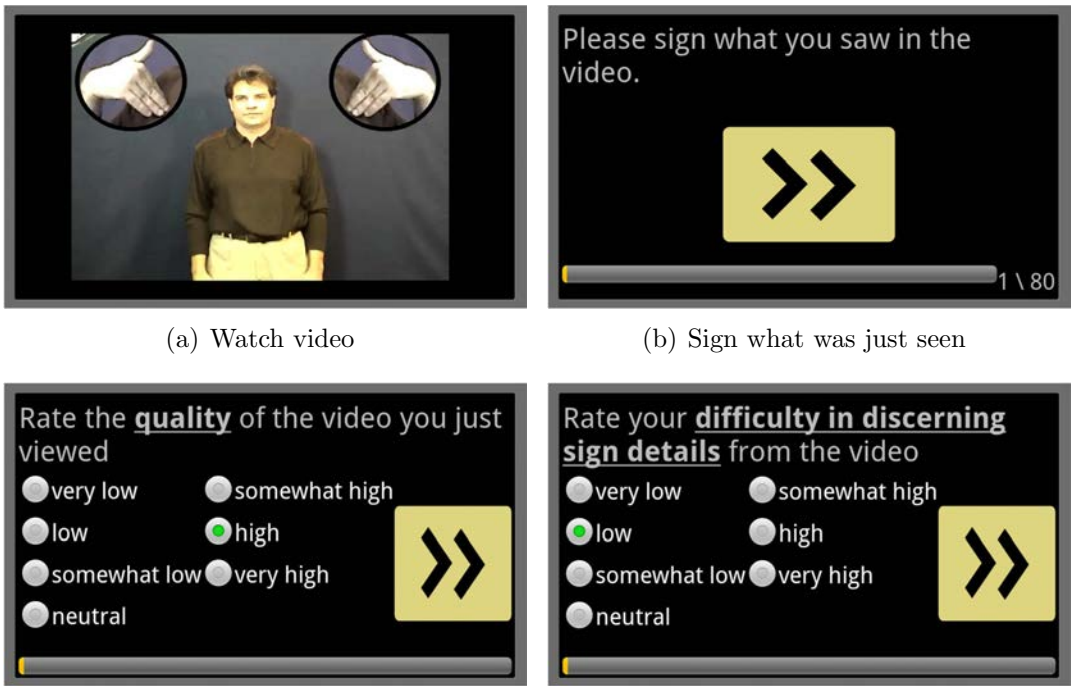
The 80 signs were separated into four groups, in order to ensure equal presentation of each condition over all of the participants in the study. Each group of signs was associated with a different condition for participants based on a partially balanced Latin square. The order of presentation for all 80 signs was then randomized so that each participant saw the words in a unique order to prevent ordering effects.

The experimental procedure is shown in Figure 6.

1. Participants watched the video for a sign in one of the four conditions, Figure 6(a).

2. After the video finished playing, participants were prompted to recreate the sign, Figure 6(b). To encourage the participant to perform the sign, the button to advance to the next screen was hidden for 2 seconds.

3. After pressing the button, participants were first asked to rate the quality of the video in terms of resolution on a seven-point Likert scale, Figure 6(c). Participants had to make a selection for the next button to appear.



(a) Watch video

(b) Sign what was just seen

(c) Rate video quality

(d) Rate video intelligibility

Figure 6: Screen progression on the mobile device

4. Participants were asked to rate their difficulty in determining the details of the sign from the video, Figure 6(d), again on a seven-point Likert scale.

This process of viewing, signing, and rating was repeated for all 80 signs in the study.

All participants viewed all 80 signs, resulting in 20 signs being displayed in each of the four video conditions. Participants were not told the meanings of the signs before being asked to reproduce them in order to prevent the participants from employing knowledge other than what they could gather from the video. This study is not about the learnability of individual signs, but instead about testing the limitations of presentation on a small display.

Participants were only able to view a video once before being prompted to recreate it. This decision was made for two reasons: first, to make the task as difficult as possible by having the video example visible only once; second, to ensure that everyone saw the video the same amount of times. If replay were possible, some participants would watch a sign multiple times and others only once, adding a confounding variable

to the data analysis. The participants' signs were recorded using a MiniDV camera. The video was later reviewed and scored by an ASL linguist. The scoring criteria is explained in detail in Section 3.4.

The experimental procedure was initially explained to the participants with screen captures of the interface. They were then allowed to practice with the study application using four videos of signs that were not part of the main study. All videos during the practice session were displayed using the highest video resolution. Before starting the main study, participants were instructed that there were a minimum of two conditions and then shown representative pictures of a still image from the high resolution condition and a still image from the inset condition. The inset condition was shown to participants so that they were not confused by the extra components upon initial presentation.

Once participants were comfortable with the experimental procedure, data collection began. Participants were invited to place the phone on a small table approximately waist-high while they were signing. Many participants chose to hold the phone when performing one-handed signs and only used the table for two-handed signs.

3.4 Results

Twenty participants were recruited for the study. Participants were between the ages of 20 and 40 with a mean age of 26.55 ($SD = 4.74$). Five participants were female, and 15 were male. Participants were asked their hand dominance because the performance of some signs is dependent on the dominant hand. Fifteen participants reported being right-handed, four were left-handed, and one was ambidextrous.

Participants were also asked to report how often they viewed video on a mobile device such as a phone or media player, because the focus of the study was on people's ability to interpret video presented on a small mobile device. Seven participants never watched video on a mobile device, and eight did so less than once a week.

Three participants reported watching video on a mobile device once a week. Only two participants reported watching video daily on a mobile device. All participants were hearing and had no previous signing experience other than some knowledge of fingerspelling.

Data collected included the following:

- **time to produce the sign** - Time to produce the sign was considered to be the time from when the video stopped playing to when the participant pushed the next button on the interface after signing.

- **quality of the videos** - Video quality was determined by the participants' responses to the seven-point Likert scale question "Rate the *quality* of the video you just viewed" for each of the 80 signs.

- **intelligibility of the videos** - Video intelligibility was determined by the participants' responses to the seven-point Likert scale question "Rate your *difficulty in discerning sign details* from the video" for each of the 80 signs.

- **participant's sign production scores** - The scoring criteria was created by a sign linguist. Participants received two points each for correct handshape, motion, and location on the body and one point for having the correct orientation. There was no partial credit for a component if partly correct, either the participant received the full points for a component or they received a zero for that component. Although a fluent signer may be able to understand the meaning of signs which are slightly inaccurate, we used a strict rating structure in order to better evaluate what kinds of errors were more likely based on video presentation.

After completing the study, participants were asked for reactions to the study including any issues with video presentation and sign production. This information will also be reported in Section 3.4.4.

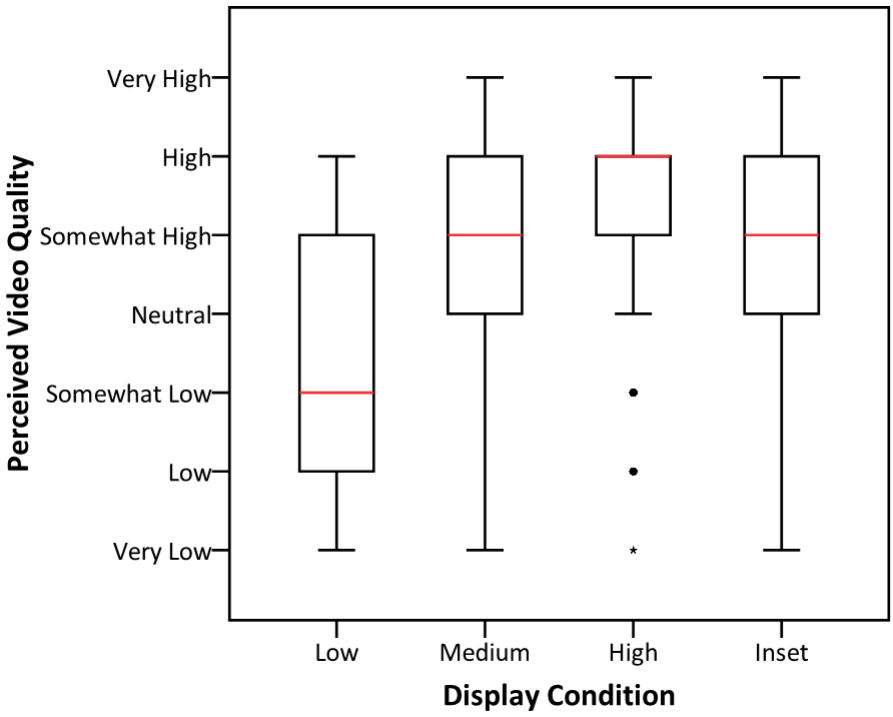
3.4.1 Perception of Video Quality and Intelligibility Analysis

This section describes the results from the participants' Likert scale responses for each video's quality and intelligibility. Although the statement regarding intelligibility was worded negatively in the study interface, for the purposes of analysis we flipped the responses so that all positive results, highest quality and highest intelligibility result in a higher rating on the Likert scale.

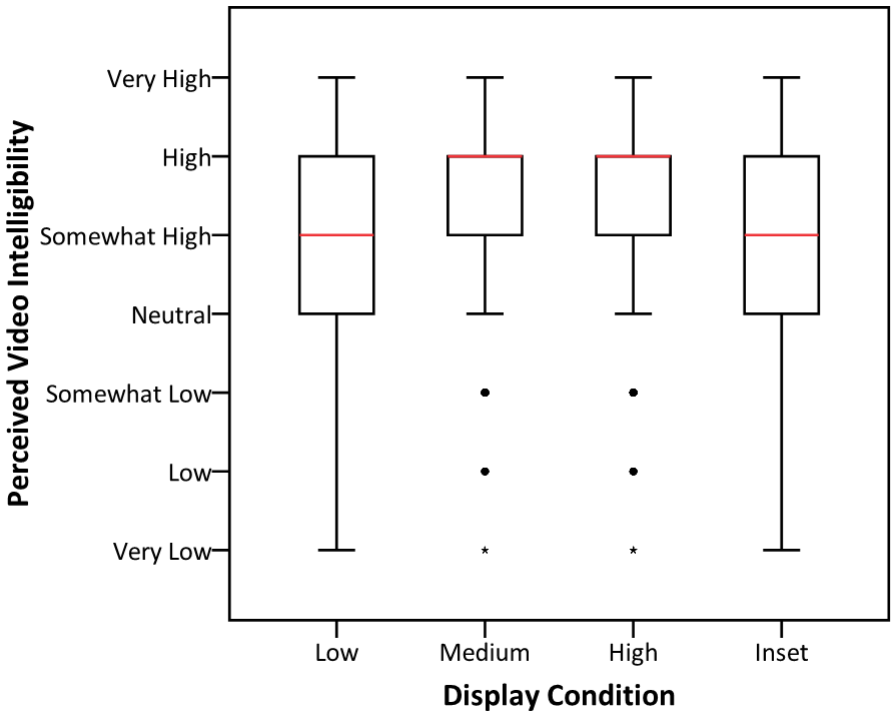
The results of the Friedman Test indicated that there was a statistically significant difference in video quality ratings across the four conditions (low, medium, high, inset), $\chi^2(3,\ n = 20) = 26.16$, $p < 0.001$. A post hoc Wilcoxon Signed Rank Test revealed that the low resolution video condition ($Md = 3.5$) was rated significantly lower quality than the medium resolution condition ($Md = 5.0$), the high resolution condition ($Md = 5.75$), and the inset condition ($r = 0.50$). The difference between the low resolution and the medium resolution conditions had a medium effect size ($r = 0.49$), $z = -3.08$, $p = 0.002$. The difference between the low resolution and the high resolution conditions had a large effect size ($r = 0.51$), $z = -3.20$, $p = 0.001$. The difference between the low resolution and the inset conditions also had a large effect size ($r = 0.50$), $z = -3.14$, $p = 0.002$.

There were no significant differences found between the medium, large, and inset video conditions with respect to perception of video quality. This result indicates that our participants were able to notice a significant decrease in video quality in the low condition, but could not distinguish between medium and high resolution videos. Figure 7(a) shows box plots of the quality ratings by display condition.

With regards to video intelligibility, the results of the Friedman Test indicated that there was no statistically significant difference across the four conditions: low ($Md = 5.0$), medium ($Md = 6.0$), high ($Md = 6.0$), and inset ($Md = 5.5$), $\chi^2(3,\ n = 20) = 4.37$, $p = 0.22$. Figure 7(b) shows box plots of the intelligibility ratings by display condition.



(a) Quality ratings



(b) Intelligibility ratings

Figure 7: Boxplots from user ratings

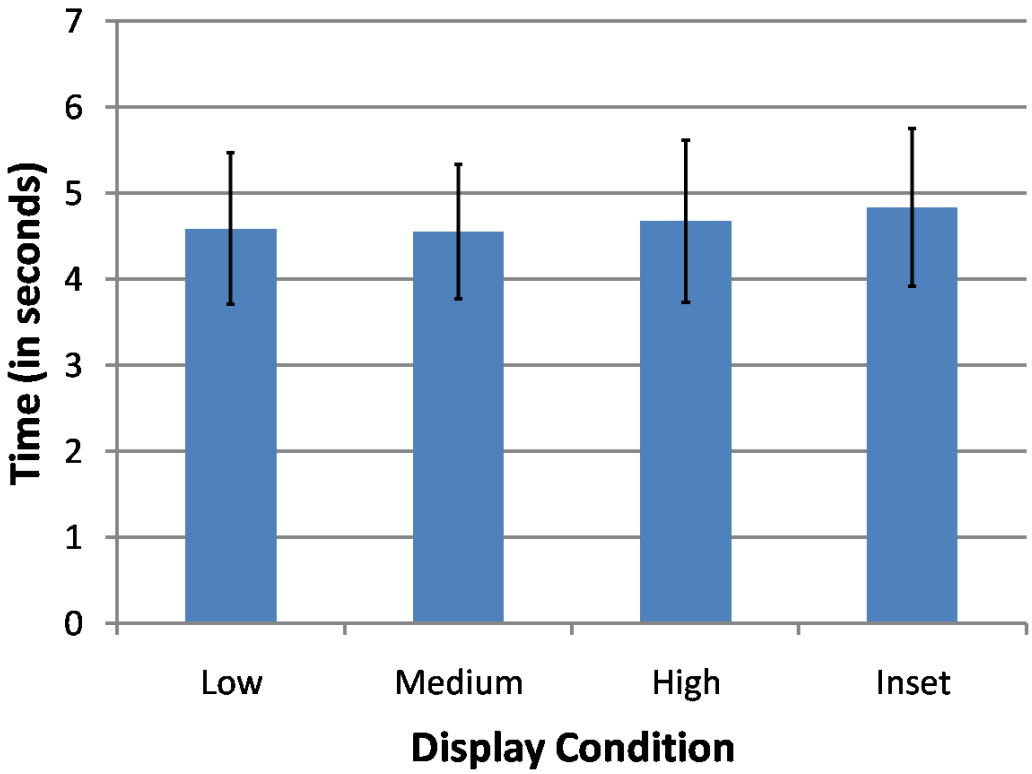


Figure 8: Average sign production time by condition

3.4.2 Sign Production Times

Timing information was logged in order to calculate the amount of time required for the participants to produce each sign. This time data was calculated by subtracting the time stamp corresponding to when the video stopped playing from the time stamp corresponding to when the participant pressed the "next" button after sign completion.

A one-way repeated measures ANOVA was conducted to compare sign production time under four conditions: low, medium, and high resolution as well as the inset video condition. There was not a significant effect for condition, $F(3, 17) = 1.60$, $p = 0.22$. The time to sign did not change based on the video's condition of presentation. The average sign production times by condition are presented in Figure 8. The error bars represent one standard deviation from the mean.

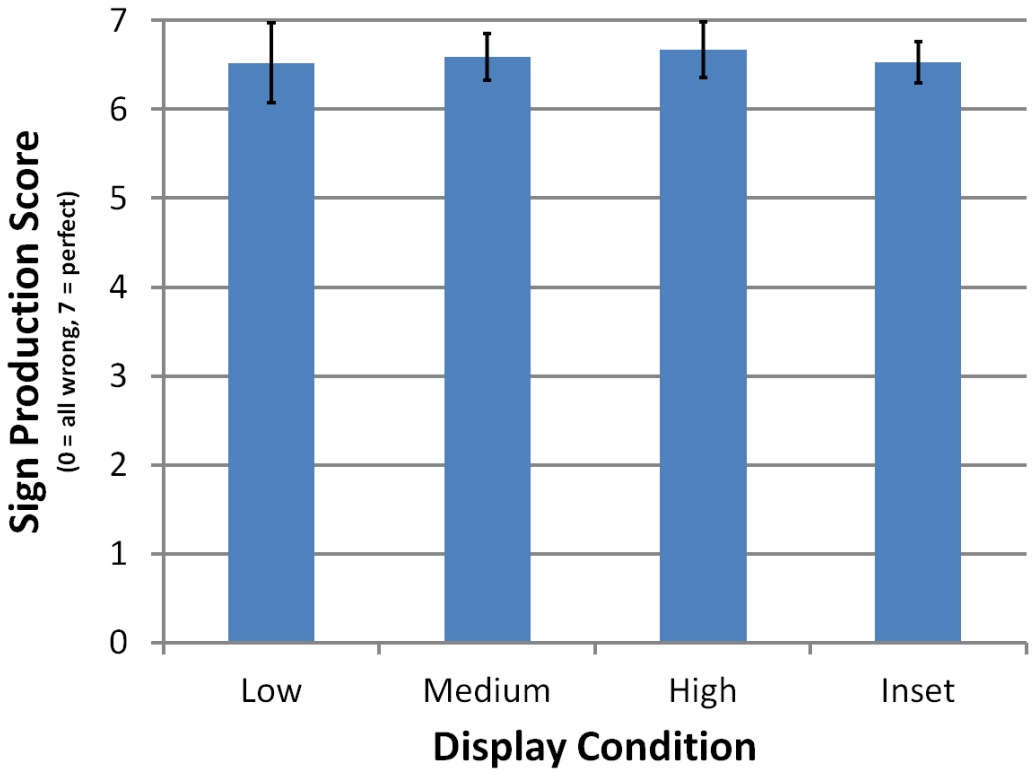


Figure 9: Average sign production scores by condition

3.4.3 Analysis of Sign Production

The results of a one-way repeated measures ANOVA indicated that there was no statistically significant difference in sign production scores across the four conditions: low, medium, high, inset, $F(3, 17) = 2.40$, $p = 0.08$. These results are summarized in Figure 9. The error bars represent one standard deviation from the mean. When one-way repeated measures ANOVAs were calculated for all of the sub-parts of the sign production scores there were also no statistically significant differences for handshape ($F(3, 17) = 1.98$, $p = 0.13$), motion ($F(3, 17) = 0.81$, $p = 0.49$), location ($F(3, 17) = 0.26$, $p = 0.86$), or orientation ($F(3, 17) = 1.00$, $p = 0.40$). The means and standard deviations of the handshape, motion, location, and orientation component sub-scores for sign production are summarized in Table 2.

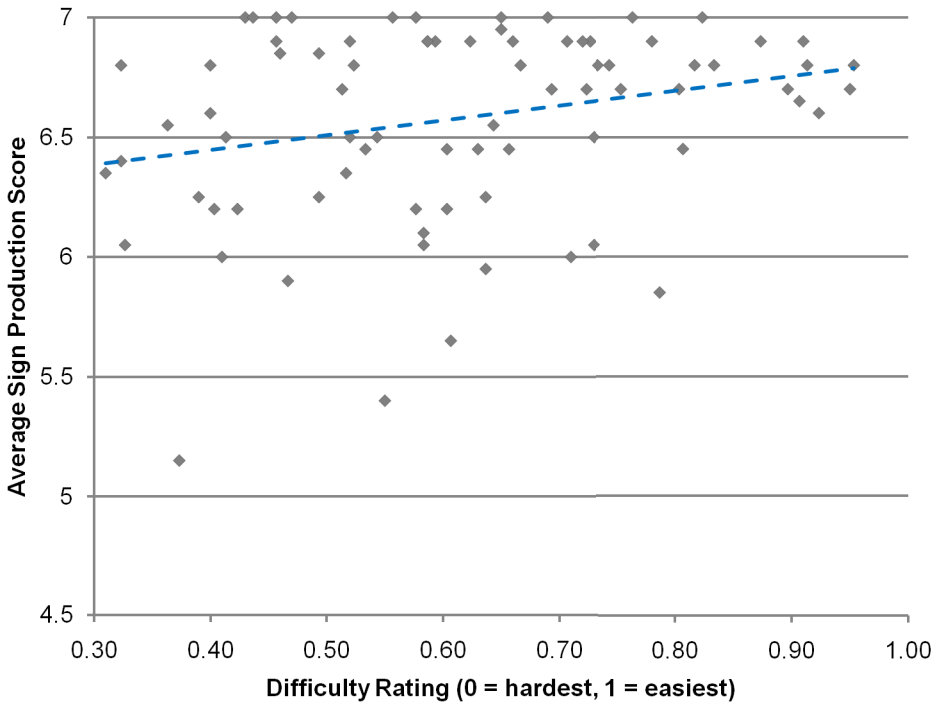


Figure 10: Relationship between sign difficulty and sign production scores

Figure 11: Comparison of signs for which participants used their right hand as dominant versus participant handedness

Table 2: Means and standard deviations of sign production components by condition

Condition	**Handshape** M(SD)	**Motion** M(SD)	**Location** M(SD)	**Orientation** M(SD)
Low	1.78(0.17)	1.86(0.19)	1.92(0.14)	0.96(0.05)
Medium	1.80(0.17)	1.88(0.13)	1.93(0.09)	0.98(0.03)
High	1.87(0.13)	1.89(0.16)	1.94(0.09)	0.98(0.04)
Inset	1.78(0.14)	1.85(0.14)	1.93(0.08)	0.97(0.06)

The relationship between sign difficulty (as measured in a study by Henderson-Summet et al. [44]) and sign production scores (as rated by the sign linguist in this study) was investigated using the Spearman rho correlation coefficient. There was a small, positive correlation between the two variables, $r = 0.22$, $n = 80$, $p = 0.049$, with easier signs associated with higher sign production scores (see Figure 10).

Participants were intentionally given no instruction on which hand should be performing which aspect of the sign. Adjustments to video presentation based on handedness were not made, in order to see how participants would interpret the video. Figure 11 shows a box plot of the percentage of signs for which participants used their right hand as dominant versus participant handednes: right, left, and ambidextrous. An independent-samples t-test was conducted to compare the percentage of times the right hand was dominant for right-handed and left-handed participants. There was no significant difference in production scores for right-handed individuals ($M = 84.3$, $SD = 34.3$) and left-handed individuals ($M = 71.3$, $SD = 32.9$); $t(17) = 0.68$, $p = 0.50$ (two-tailed).

3.4.4 Participant Responses

After completing the study, participants were asked for feedback on their experience. This information is valuable in determining how future ASL learners will be able to interact with the sign videos.

The inset condition received the most negative feedback. Eight out of the 20 participants reacted negatively to the inset condition. Participants remarked on the

difficulty of visually attending both the handshapes presented in the insets and to the motion of the video at the same time. One participant said "If you look at the inset first, then look at the motion, you don't know what the action was." This result is one disadvantage of a study design with only a single presentation of a sign. Another participant reported that there was a trade-off in the inset condition. In really complex signs, there was too much occurring, both from changing handshape insets and in the motions from different parts of the body. In really simple signs, the insets were unnecessary. Even so, for some medium difficulty signs, the insets were sometimes helpful as reported by two of the participants.

Three participants reported wishing that they could repeat the video on the longer, more difficult signs. This ability may make the inset condition more desirable and less of a distraction since the learner could focus on different aspects of the sign on different viewings. Five participants also suggested reducing the speed of the video. The ability to change sign speed would be very helpful for learning more complex signs. However, the application should default to the original sign speed so that novices get used to normal signing. The ability to replay a sign at a slower speed might help them learn the signs by allowing a longer opportunity to view all components of a sign.

Seven of the 20 participants reported that they did not feel the resolution or quality of the video was what determined their success at reproducing the sign. Six participants reported that they felt the difficulty of reproducing a sign was determined more by the complexity of the sign.

Another potential area for further investigation suggested by some of the participant comments relates to hand dominance. The video was not manipulated (i.e., flipped left-right) based on a participant's reported hand dominance, in order to determine how viewers with no knowledge of sign respond to the video. Three participants made remarks relating to interpreting signing handedness in the video. One

participant did not directly ask about handedness but remarked that the hardest part of signing was determining which hand should be performing what action. This issue may potentially be solved by providing a lesson on hand dominance and/or by reducing the playback speed of the video. The other two participants comments were directly about hand dominance. One participant reported mapping their own right hand to the signer's right hand. Another participant asked at the beginning whether they should mirror the signs or flip them. When told to do whatever was easiest, the participant decided that it was easier to mirror the video.

3.5 Discussion

Although participants noticed a significant difference in sign quality between the low resolution display condition and the other three display conditions, the use of low resolution video did not significantly impact the time required to produce signs, the intelligibility of the videos, or even the quality of the participants' repeated signs. This result is positive because it indicates that the use of smaller, low resolution videos in an ASL learning system does not adversely affect the intelligibility of the signs. An advantage of using smaller file sizes is that it will be possible to store more signs on the phone's memory card. Also, if new videos need to be downloaded from a server, it will require less time and less bandwidth due to the smaller file size. If an interface has a shorter time to access and navigate, then it will tend to have higher usage [106].

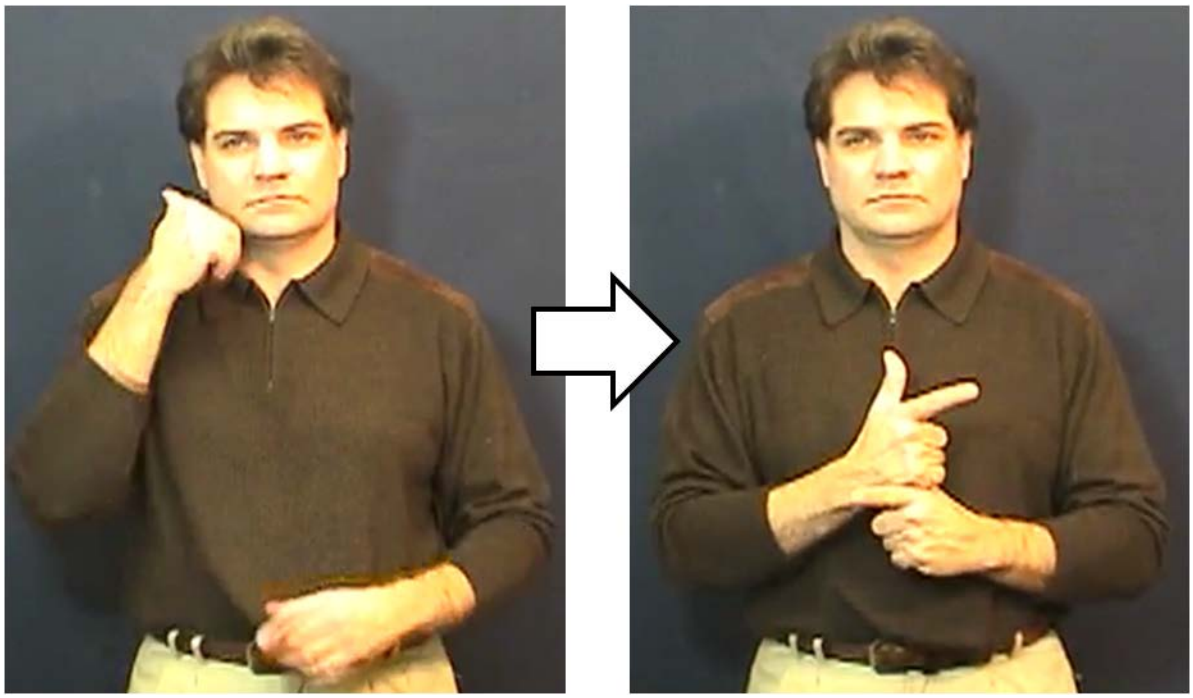
Participants were correct in their observations that the difficulty of the sign was related to how well they were able to reproduce the sign. There was a significant relationship between the difficulty of a sign and the average sign production score in this study. This result indicates that in future studies more attention should be paid to how participants interact with the system while learning more complex signs such as SISTER (Figure 12(a)), which were the signs most often incorrectly reproduced in

this study. More opportunities to view these difficult signs or more options to view the video at different speeds might help the participants to learn to sign SISTER as well as they were able to sign easier signs such as HUNGRY (Figure 12(b)).

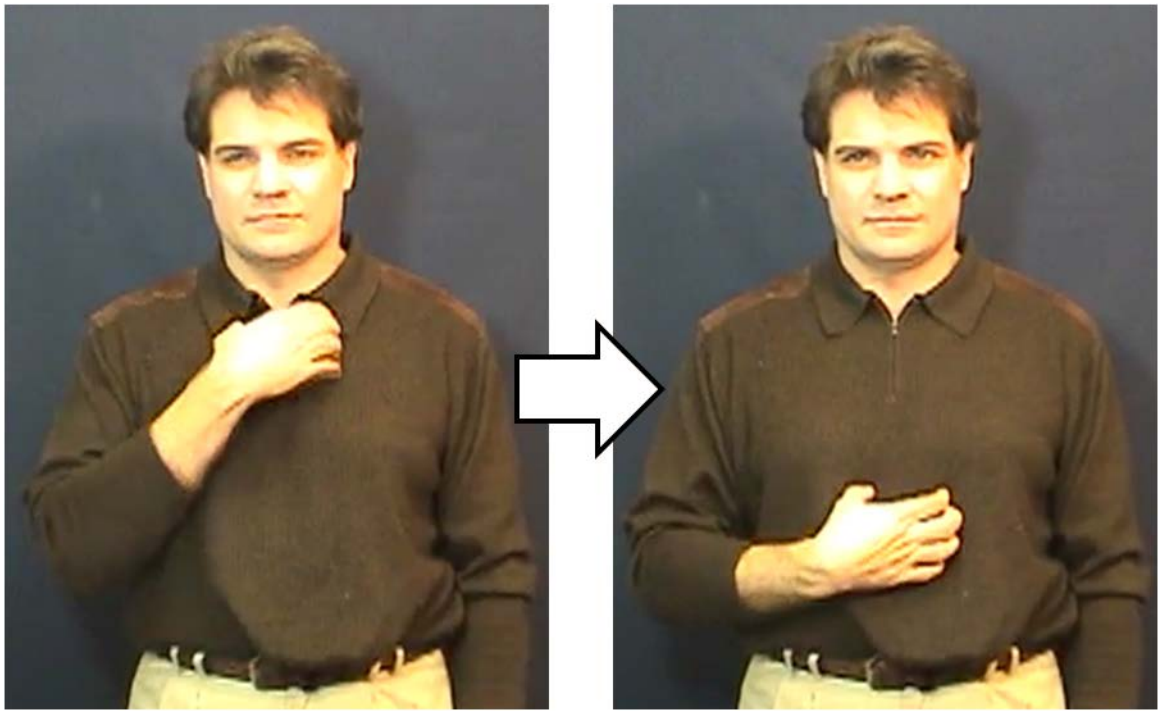
Even the signs that participants reproduced correctly the least often received fairly high scores. Only six signs received average scores lower than six points. Those six signs were SISTER ($M = 5.15$), TRUCK ($M = 5.4$), PERSON ($M = 5.65$), BEDROOM ($M = 5.85$), HOT ($M = 5.9$), and SICK ($M = 5.95$). The relatively high performance across all signs indicates that a mobile device is appropriate for learning how to sign.

Figure 13 shows still images from the six most difficult signs as well as charts of average production scores broken down by the four components: handshape, motion, location, and orientation. For three of these signs: SISTER (Figure 13(a)), TRUCK (Figure 13(b)), and PERSON (Figure 13(c)) participants had the most difficulty with providing the correct handshape. Participants also had difficulty with handshape for HOT (Figure 13(d)) and SICK (Figure 13(e)). However, when signing HOT, participants also had difficulty with providing the correct orientation. When signing SICK, participants had difficulties recreating the correct motion. The sixth sign, BEDROOM (Figure 13(f)), is the one difficult sign for which participants had no problems with the handshape, but instead motion was the biggest source of error.

Participants did not show consistent patterns of using a dominant hand in their signs. Figure 14 shows how one participant was inconsistent signing with a single dominant hand even with two very similar signs. There was also no significant difference between right- or left-handed participants using their right hand. Some participants explicitly asked what strategy they should use to interpret the videos, and even they were not consistent in following their strategy. If the one participant's observation was correct, and it was actually easier to mirror the sign than to match the handedness of the video, then we should have seen a higher prevalence of left-hand

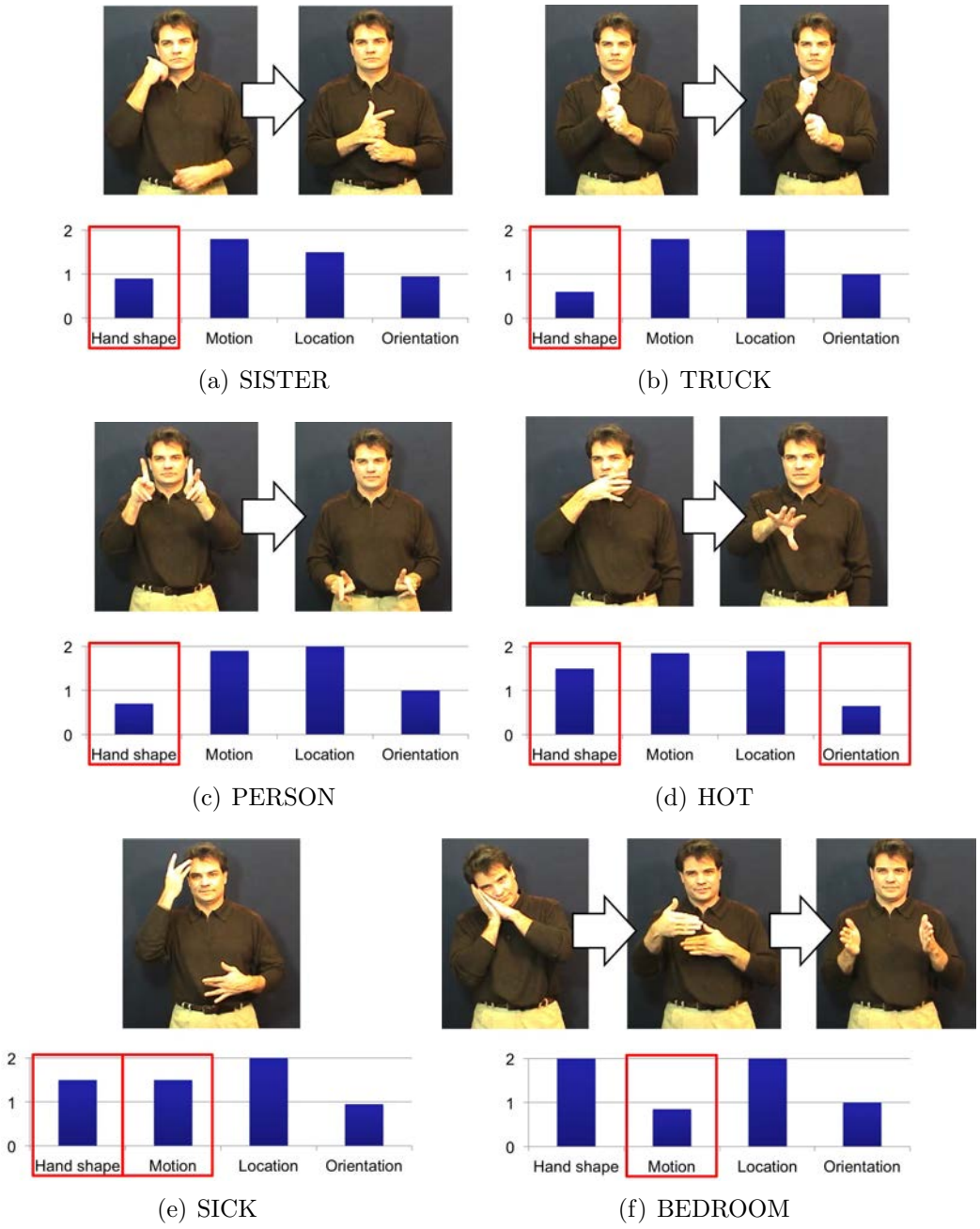


(a) SISTER



(b) HUNGRY

Figure 12: Screenshots from the videos for one of the hardest signs to reproduce, (a), and one of the easiest, (b)



(a) SISTER (b) TRUCK

(c) PERSON (d) HOT

(e) SICK (f) BEDROOM

Figure 13: Production errors on the six most difficult signs

(a) Flipping to sign GRANDFATHER (b) Matching to sign GRANDMOTHER

Figure 14: Dominant hand inconsistency

dominance. This inconsistency is evidence that early in the usage of a ASL learning system it will be important to both inform the learners about the role of the dominant hand in signing as well as allow the users to choose what presentation strategy they would like to use: mirrored signing, where the learner mirrors what the video shows, or matched signing, where the learner matches the actions of his or her right hand with the actions of the signer's right hand in the video.

3.6 Conclusions and Implications for Future Work

This chapter presented a study investigating the intelligibility of various video presentation methods for novices learning ASL. The results show that it is not necessarily the quality of the video that influences a person's ability to reproduce the sign but the difficulty of the sign itself. Although some participants remarked that they preferred the higher quality videos, video quality did not impact their ability to reproduce

the signs. The relatively high sign production scores across all signs indicates that learning to sign correctly on a small device is possible.

Findings indicate that one potential improvement is to incorporate the ability to change the speed of playback for videos. Allowing viewers to alter the playback speed may help them to learn the details of the sign better. Perhaps playback at slower speeds and allowing an option to replay a sign video could improve the usefulness of embedding handshape insets in the video. Because low resolution videos did not degrade the participant's ability to reproduce the signs, I will also be able to rely on an already large library of sign videos in a low resolution format, available through the MySignLink website. The ability to use these lower resolution videos means that there will be a larger library of videos available to the parents upon deployment of the system. However, participants were, able to tell the difference in quality between low and high resolution videos. Consistently watching low resolution videos may adversely impact user experience and a user's willingness to use the application. The lower resolution videos should not be a permanent replacement for high resolution versions of the videos.

http://cats.gatech.edu/cats/MySignLink/index.htm

CHAPTER IV

INTERVIEW STUDY OF PARENTAL ASL LEARNING NEEDS

4.1 Introduction

I conducted interviews with members of the target population to ensure that SMARTSign is designed to provide appropriate types of assistance to hearing parents attempting to learn ASL for their young deaf children. These interviews were focused on understanding parents' motivation for learning ASL, their existing methods and support for learning, participants' reactions to the SMARTSign prototype, and their current mobile technology usage.

4.2 Related Work

Two similar interview studies have been carried out with parents of deaf children on a number of relevant topics [49, 79]. However, they did not explicitly interview parents about their learning habits to understand difficulties when learning ASL.

Jackson et al. carried out interviews with nine parents of eight children to assess parental needs [49]. The children's ages ranged from one to to 19. The goal of the interview was to make recommendations to service providers on how best to serve families with deaf children in early interventions. They found that parental communication decisions were based on a desire to maximize hearing and speaking,

Portions of this chapter are excerpted from Kimberly Weaver and Thad Starner, "We need to communicate!: helping hearing parents of deaf children learn American Sign Language" in the proceedings of ASSETS, 2011 [116]

parents' information sources, health and safety concerns, and others reactions. One key finding from the interviews was that parents said time demands from caring for their deaf child were "equivalent to caring for two to three children." We had already assumed that demand on parent time was one reason why it was difficult for them to learn ASL. Managing additional time for doctor and speech therapist meetings for their deaf child can also put a significant limit on parental availability.

Meadow-Orlans et al.'s data comes from a mixed methods approach including surveys, individual interviews, and focus group interviews [79]. The purpose of their study was to gain basic understanding of the experiences of parents of young deaf children. They focused on reactions to identification, communication method decisions, and reactions to care providers. Parents sometimes had no choice over what communication methods they used; instead they were frequently limited by the opportunities available to them based on their place of residence. Two reasons cited for parents' decision to sign included giving their children any chance they could to communicate and leaving as much choice in the hands of their children when they were older. Mothers rated their skills in ASL better than the fathers 95% of the time. One potential area for investigation could be exploring the opportunities for supporting fathers' learning ASL using SMARTSign.

Vaccari and Marshark wrote a summary paper on the impact of parental communication ability on a deaf child's development [114]. They found that the deaf children who are most competent in social and language development are those whose parents engaged them actively in linguistic interaction from a young age. Linguistic interaction can be difficult for hearing parents with deaf children because they have so little formal ASL training that they cannot use it for daily needs, feel uncomfortable signing, and only sign when directly addressing their child. One goal of my interview study is to determine how to address these three problems.

4.3 Method

My interview study took the form of a semi-structured interview with hearing parents of deaf children. The interview topics followed four categories:

- *Family* - The goal of the family topic was to understand basic background information about the parents and their deaf children to determine the level of support parent and child had for learning ASL.

- *ASL Learning* - Conversation about ASL learning was directed towards uncovering current difficulties parents experience while learning ASL in order to determine if SMARTSign can be designed to alleviate those difficulties.

- *Prototype Reactions* - Parents were shown the prototype SMARTSign system to gauge reactions and determine both utility and desirability of the existing functions.

- *Phone Ownership* - Because the ultimate goal of this research project is to deploy a working system to parents long-term, the phone ownership topic was important for understanding what devices were favored by parents and availability of data plans.

Appendix B provides a detailed list of the types of questions asked during each interview.

4.3.1 Parental Recruitment

Parents were recruited through a number of methods. E-mails were sent to both the SKI-HI (Sensory [Kids] Impaired Home Intervention) coordinator at Georgia PINES, the state-wide early intervention program for Georgia, and to the social worker at the Atlanta Area School for the Deaf. Parents were also recruited from the 10th Annual Early Hearing Detection and Intervention Conference (EHDI 2011) in Atlanta,

Georgia. EHDI is a national conference with tracks for both practitioners and parents. Only one parent was already acquainted with the SMARTSign project before participating in the interview. She was a regular user of an early web-based iteration of the project.

4.3.2 Participant Demographics

Eleven parents were recruited for the interview study: nine mothers and two fathers, representing ten different families. One of the participants is currently a single parent, and one of the participants was a single parent when her child was born but is now married. The other eight families represented two-parent households. Due to recruitment at a national conference, participants represented eight different states from three geographic regions of the United States: the Southeast, Northeast, and Midwest. A summary of the participant demographics is shown in Table 3.

Table 3: Summary of participating family demographics

Family	**Interviewed**	**Region**	**Children** (Hearing:Deaf)	**Child Age**	**Identified**	**Sensory Device**	**Medical Issues**	**Learning Duration**
1	mother	Southeast	(0:1)	8 yrs	2 yrs	CI		6 yrs
2	mother	Northeast	(2:1)	3.5 yrs	3 mos	hearing aid		2.5 yrs
3	mother	Southeast	(1:1)	16 yrs	13 mos	CI (does not use)	meningitis	13 yrs
4	mother	Southeast	(2:2)	3.5 yrs & 2 yrs	18 mos & birth	hearing aids	cystic leukoencephalopathy	1.5 yrs
5	mother	Northeast	(6:1)	6 yrs	2 yrs	CI (does not like)		4 yrs
6	mother	Northeast	(1:1)	4 yrs	birth	CI		3 yrs
7	mother	Southeast	(1:1)	5 yrs	birth	CI & hearing aid	autistic	5 yrs
8	mother	Midwest	(0:1)	10 mos	5 mos	hearing aid		4 yrs
9	father	Midwest	(1:1)	5 yrs	birth	hearing aid		3 mos
10	mother & father	Southeast	(0:1)	4 yrs	3 yrs	CI	maternal drug usage, adopted	2 yrs

The parents interviewed had between one and seven children ($\mu = 2.5$, $\sigma = 1.84$). All of the participants were the parents of at least one deaf or hard of hearing child. One mother had two children who were hard of hearing. Three of the parents only had one child.

The ten families included 11 deaf or hard of hearing children. Their deaf children's ages varied between 10 months and 16 years ($\mu = 5.26$ years, $\sigma = 4.04$ years). The age of their child's hearing loss identification also ranged from birth to three years ($\mu = 11.18$ months, $\sigma = 12.65$ months). Four of the children were identified at birth. Many of the parents reported that their children had initially failed their neonatal hearing tests but passed on follow up tests, leading to delayed diagnosis. Despite the late identification of deafness for some of the children, only one child's deafness was not congenital or acquired shortly after birth. This child became deaf after suffering from meningitis at 13 months. Three of the eleven children had other serious medical conditions. This ratio is consistent with the findings of Meadow-Orlans et al. [79]. The two deaf siblings have cystic leukoencephalopathy which is a progressive degeneration of the brain's white matter. Another child is autistic. One child is adopted, and the birth mother abused drugs: high levels of bilirubin (extreme jaundice) caused the deafness which was not diagnosed until the child was three years old.

All of the children possessed some form of sensory device: hearing aid or cochlear implant (CI). Five of the children had at least one ear with a CI although two parents reported that their children did not like to wear their implants. Five of the children wore hearing aids. One of the children wore a CI and a hearing aid.

4.4 Motivation for learning ASL

Discussions with educators and social workers early in the SMARTSign development process led to the impression that parents might not be interested in learning ASL.

Our opinions changed when we deployed a prototype ASL dictionary to hearing parents with deaf children called SignKick. We expected parents to simply show the ASL videos to their children when they wanted to communicate. Instead parents would look at the videos and practice the signs in them until they could sign the phrases to their children.

In our interviews, we learned parents had a number of reasons for deciding to learn ASL. The primary reason was communication with their child which is consistent with previous parent interview studies. Some parents also expressed an interest in providing their children with a bilingual education and access to the Deaf community. Parents also related some negative factors that made their decision more difficult.

4.4.1 Communication

Eight of the ten families said that a desire for communication with their child was a reason for their decision to learn ASL. One mother said that when her parent mentor came to her home and told her all of the potential options her decision was based on how her son could learn language the fastest. Other parents felt like they had no choice, their area only provided support for one communication method. For some it was not really a conscious decision but seemed like the only option they had. Communication was not happening by any other method, and they "had to do something."

One mother realized that she had to work harder to learn after an experience at an amusement park. Her son was four and playing in the pool, so was not wearing his cochlear implant. The lifeguard was whistling at him to tell him not to climb over the edge. Without his implant, the son could not hear the whistle. The mother had no idea how to attract her son's attention, and she felt embarrassed when all the other families turned to stare at her. When she tried to take her son away, he could not understand her.

The Baby Sign movement is having a positive effect on parents' willingness to learn ASL. Two mothers stated that they had already planned on using ASL with their child before their child's diagnosis. One mother had already used Baby Sign successfully with her two older children. She said it did not feel as "scary" as she feels it might be for others because of her prior exposure. Another mother said that she had always wanted to teach her children ASL and her husband pointed out that desire when they learned their child was deaf. Her reaction was to say "that's not the point" – there is a difference between learning a handful of vocabulary by choice as a temporary measure while a child is young and learning a new language as a primary means of communication.

Some parents treat ASL as a temporary measure until their child gets an implant, their hearing aids allow them to learn language, or their hearing gets better. In some cases a transition to oral communication might be possible. One mother related how as her son masters a spoken word, he will drop the use of the relevant sign. This viewpoint can also backfire. One mother said they had started learning ASL, and then they stopped when he was implanted. At age three, their son had behavioral problems due to lack of communication. They then decided to start signing again and have continued doing so for 13 years.

In two other cases, this lack of communication became so apparent that their child became very frustrated. One family said that they and their son were frustrated because they did not know what he wanted, and they didn't know how to respond to him. Another mother said that knowing single words was not enough to ease the communication barrier.

If parents wait too long to learn ASL, they find they have to work harder to be able to match the child's higher language abilities. One mother reported experiencing this situation. The child became the language model for the parent. This situation becomes frustrating, not just for the child, but for the parent as well.

4.4.2 Linguistic and Cultural Benefits

Parents also made the decision to learn ASL for more than just communication. Three parents expressed interest in ASL as a way to provide their children with a bilingual education. One mother said "we always considered it an option because if nothing else, we figured he'd be bilingual." This sentiment is evidence that old ideas that learning one language impairs the ability to learn a second language are becoming less prevalent. Bilingualism is now thought of as an advantage rather than a disadvantage. Another parent said a bilingual education would help her child "learn as much as possible." One father took his son to Gallaudet (the university for the Deaf) in Washington DC shortly after his child was identified. Despite pressure from those in his community who wanted him to focus on one communication method, either oral or signing, the father said that they wanted to "empower him [their son] with choices." The father said that their son would then have the opportunity to choose his desired communication method later.

Two families mentioned the role of the Deaf community in their decision process. One parent said that he wanted to learn ASL because it was the language of choice for the Deaf community. Another parent said the experiences of a Deaf friend who learned sign first and then started learning oral language convinced them to learn ASL. In the first example the father is learning ASL to help his child gain access to the Deaf community. In the second example, the Deaf adult served as proof that ASL did not hurt a child's chances to eventually learn to speak.

ASL has one other benefit for parents, as expressed by one of the fathers. In this father's state of residence, the dominant language promoted by early education providers is Signed Exact English (SEE). SEE is not a natural language, but it is a visual language based on English grammar. SEE goes farther than just signing words in English word order and also includes signs for word endings such as "-ed" and "-ing." The father said that SEE was unnatural, too difficult to learn, and his son

had given up using it. The feeling of dislike for SEE's difficulty and appreciation for ASL was shared by another mother.

Two of the parents made a point to emphasize that their children were normal, though deaf. These parents focused not just on communication with their child but inclusion in family life. One mother, after listening to stories by Deaf individuals who spent their childhoods sitting at the dinner table not being engaged by their family and not knowing the names of their aunts and uncles, resolved that her child's experience would not be the same. Another father went to visit Gallaudet to make sure he explored all of the opportunities his son could have and to ensure that all possible avenues were open for his child to choose. Both of these parents are working to make sure to find ways to make their children's childhood "the best possible experience," as one mother expressed.

4.4.3 Disincentives

There are a number of disincentives which make the decision to learn ASL difficult. One mother related her annoyance of going out and having people stare at them. Kids would come up to her and ask what was wrong with her son. Using a visual language automatically singles you out as being different, which can be uncomfortable for parents.

Lack of prior experience with deafness can make it difficult to embrace a new language and culture for their child. Only one parent had prior experience with Deaf individuals before their own child's identification. One mother was a special education teacher even before her child was identified. She said that all she was taught about deafness in school was "deaf is bad."

ASL is not an easy language to learn. Even parents who have been learning ASL for many years are hesitant to say they know or use ASL. A mother claimed that the sign they used in the house was more of a pidgin of ASL. One mother, who works in

her son's school, says that she is uncomfortable when she is asked to read "aloud" at school because she is constantly worrying about whether she is signing correctly. She also said that when she first started signing she was afraid to sign in the grocery store for fear that people might see her doing it incorrectly. One father stopped signing because his child said his signing was bad and was embarrassing. Now the father does not have the confidence to use ASL with his own Deaf friends.

Treating ASL as if it is a temporary language before oral English is acquired can be another disincentive to learning ASL fully. As technology for hearing aids and cochlear implants advances there are some individuals who are able to gain enough ability to interact in hearing society without the need for ASL. Religion can also play a role in the belief that ASL knowledge is only a temporary necessity. None of the parents expressed this belief personally but one father related an experience he had with his father. The grandfather quoted how Jesus healed the deaf, the blind, and the mute, implying that faith could heal his grandson as well. The father's reply was "My son is not broken. He is whole. He just happens to be whole and not hearing." This attitude is more likely to help his child develop the skills necessary to succeed in a hearing society.

Another barrier to learning ASL is lack of opportunities to practice. Two mothers talked about their lack of opportunity. One mother has experienced frustration because her son is autistic. She feels that the response from her son is not enough for her so she will seek out other forms of communication. Later, she did state that he does surprise her sometimes when he uses a sign that she was unaware he knew. The mother whose child is still an infant talks about how difficult it is when she cannot use her ASL every day. Her child does not yet have the capacity to learn more complex language, so she has to work and focus on learning so she is ready to teach when her child is ready.

Table 4: Summary of learning tools

Learning Tool	Positive	Neutral	Negative	Total
Early Intervention Services	4	1	1	6
DVDs	4	2	2	8
Websites	2	6	1	9
Classes	3	1	3	7
Mobile Phone	0	2	0	2
Books	1	2	4	7

4.5 Learning Tools

Participants were asked about the tools they used to learn and practice their ASL skills. While most parents agreed that classes were the most beneficial, they reported using a wide range of tools including books, DVDs, and websites. Some parents even talked about tools they used while they were mobile. Many states provide services for parents where an educator will come into the home to help parents and family members. Table 4 shows a summary of participant use of, and reaction to, a number of different tools for learning ASL. We will start by investigating characteristics of the tools which had the most positive reactions (Early Intervention Services) and the most negative reactions (books).

4.5.1 Interventions

Early Intervention Services received the most positive comments of any of the other learning tools. Of the ten families, six had access to early intervention services. These services are typically provided for the family while the child is between the ages of zero and three and can provide many different forms of assistance. One parent was matched with a Deaf mentor. The mentor played a significant role in helping the mother with her confidence in learning ASL and with helping her feel comfortable interacting with the Deaf community. Other home providers help parents by teaching them ASL in their homes. One home provider taught the extended family as well as the parents in their home once a week. Home providers can also help parents learn

event-specific vocabulary. One mother whose home provider visits twice a month talked about looking ahead at the calendar and asking her to help with vocabulary related to visiting the dentist office so that her son would not be nervous. Another service can be helping parents keep pace with vocabulary related to the topics their child is learning in school. A third way home providers can assist parents is by helping them with the transition to communicating in a more visual language. One parent talked about how his early childhood educator did a good job of teaching about communication and turn-taking to help them understand how to convey the significance of the signs to their child. Early Intervention Services are generally positive experiences for parents because they are largely customized to the family, providing relevant and timely information.

Not all reactions to the home providers were positive. One parent commented about the wide range of potential personalities and styles. She commented that one home provider argued with parents about the proper way to perform signs. Given that parents are already experiencing low confidence with their ASL skills, this confrontational style could discourage them further. Parents may also feel overwhelmed by the amount of information provided by their home providers at once. Despite these problems, the parent admitted that she knew the home providers meant well and that it was better than not having any support like those who lived in more rural regions of her state. The disadvantage of Early Intervention Services then lies in the variability of the home providers.

4.5.2 Books

Parents reacted to books the most negatively. Seven of the ten families reported using books to help them learn ASL. Of those seven families, four of the parents were not happy with the books they had. Parents found them difficult to understand. Because motion plays a large role in the meaning of a sign, it can be difficult to

convey a complete sign through static images. One mother said it was difficult to look at a single picture with lots of arrows pointing in "seemingly random" directions and determining what to do. One father said that he does not know the sign for FOREVER because of the two dimensional representation. He knows how the sign ends but cannot figure out how to start the sign.

Parents reported owning big ASL dictionaries, pocket dictionaries for quick reference while mobile, text books, and other reference books. All of these books are focused on vocabulary acquisition. One parent who reported not owning any books lamented the lack of real books in ASL to enable her to tell stories to her child.

4.5.3 DVDs

DVDs, while still focusing primarily on vocabulary, do have an advantage over books in their ability to present signs in a more understandable format. DVDs were employed by eight of the ten families. The Signing Time series was the most popular with five of the families reporting its use. Signing Time is targeted at helping children learn signs, but many of the parents felt they learned a lot from them as well. One mother said that the fact that the videos had sound with them helped because she could put the DVD on and then when the DVD said a word she was interested in learning she could pay attention. With DVDs without an auditory component it was easy to start playing one and then get distracted and realize an hour later that they were supposed to be learning. Parents liked DVDs because they were able to see the whole sign and how it was performed, unlike with the books.

Parents sometimes became frustrated with the DVDs because they were mostly focused on vocabulary. The songs provided a little bit of flow, but for the most part the signs were not being presented together to create full phrases. One parent said there was too much extra in the DVDs, and they just wished they could get to the vocabulary. Another disadvantage with the DVDs is that there was no assistance

when experiencing difficulty learning a sign. The only choice was to watch the section of the DVD over and over again until understood. DVDs are meant to be played and watched for a duration; they are not as useful for quick referencing.

One parent reported having an ASL story DVD and said he could follow the signs generally word for word, but it would make him confused when the video showed a classifier. Classifiers are signs that represent a general category of objects. Classifiers in ASL are similar to pronouns in English in that the referent depends on their context of use. They can be used to represent an object, how it moves, or how it relates to other objects. This difficulty with the ambiguity of classifiers is understandable for parents who have had a largely vocabulary-based ASL education with little or no exposure to conversational artifacts such as classifiers.

4.5.4 Websites

Websites are becoming more popular with parents. Only one family reported not using websites to help them learn ASL. Most families use dedicated sites for ASL such as ASL Pro, lifeprint.com or SigningOnline. All of the websites provide a dictionary. Some are not browsable without acquiring a login which may cost money. Lifeprint.com provides different workbooks and practice tools. SigningOnline provides access to course material for a fee. Two families reported using generic search strategies for finding sign videos online. One family uses YouTube. Another family searches for signs using Yahoo! and the search terms "sign language for" to find vocabulary. The problem with the Yahoo! strategy is that sometimes she gets videos that are not what she is looking for. It can be a very slow process to weed out the inappropriate videos.

The advantages and disadvantages of the websites are similar to those of the DVDs. Parents like seeing the videos of the actual signs instead of the illustrations they find in books. They also feel like they want to see more than just vocabulary.

Support for more connected sign is limited. Websites have one advantage over DVDs in that they can immediately find the sign for which they are looking. Some parents felt that it was difficult to spend a lot of time online.

4.5.5 Classes

Classes received the most divided responses of all of the tools discussed. Seven of the families have attended formal classes at some point in their attempts to learn ASL. Classes are typically offered through three different sources: higher education institutions, schools for the deaf, and churches. Two families attended classes at higher education institutions. One mother took ASL 1 at the University of Georgia while she was a student. Unfortunately ASL was not considered a language by the university so it did not fulfill her language requirement. Another family took ASL 1 at the local community college. This mother talked about the expense of taking the class when they were not interested in the course credit. Three families attended classes at their local school for the deaf. Reactions to these classes were largely positive. Parents talked about the fun games they played, the camaraderie they gained from learning with other parents in similar situations. One mother said she took ASL 1 and 2 multiple times each because every time she experienced learning from different Deaf adults. One family attended classes at their church. They felt that there was too much information at once. They were more interested in learning the basics.

Another mother who did not specify the location of her classes said that she registered for ASL classes twice but dropped them. She felt that the class took too much time. The teacher spent most of the time talking and the mother felt that she just was not learning enough to justify the amount of time spent. Over all it appears that the classes at the school for the deaf were the most accessible to the parents. More general classes were frustrating to parents who were most interested in immediate communication needs with their children.

4.5.6 Mobile Learning

Five of the parents talked about using some form of language learning tool while outside of their homes or classroom. Two mothers had small dictionaries they would carry with them to look up unknown signs. Another mother reported that every time they were in the car, she would play one of the SigningTime DVDs. Two families reported using a mobile phone for looking up new signs. One mother used the web version of the SMARTSign dictionary (http://cats.gatech.edu/mysignlink) on her smart phone to look up vocabulary. Another mother would search for words on the ASL Pro website. None of the parents mentioned using any of the applications available for the Android or iOS operating systems. All of the parents were very interested in an all-in-one application for learning ASL such as SMARTSign.

4.5.7 Other Sources

Other people also provide support for parents attempting to learn ASL: their deaf children, church community, Deaf adults, and other professionals. Three parents talked about adult acquaintances. The advantage of being around Deaf adults is that parents are able to gain experience with full conversations. As one mother said, talking with a Deaf adult is much different than a conversation with their child. Two of the parents mentioned the importance of immersion in acquiring their language skills. Both of these mothers have become involved with their child's school in order to improve their language.

One mother who has struggled with learning ASL says that now the family is mostly learning from their child. They are now playing catch up with his language skills. The family is not always sure that the signs he is teaching them are correct.

Parents will frequently ask others around them if they are unsure of a word. Two mothers talk about asking Deaf adults they know. One mother said she will talk to the speech pathologist at the school if she is unsure of a sign. The church community

can also be helpful for parents learning ASL. One father said that three people from his church immediately started learning ASL when his son was identified. Two of them are training to become interpreters. He is now learning ASL from one of those individuals.

4.6 System Prototype Response

During the interview, parents were presented with a prototype of the SMARTSign system. They were asked for reactions to the current components as well as suggestions for improvement. Possible expansions of the system were described, and parents reflected on the impact or importance of the proposed additions to their own learning.

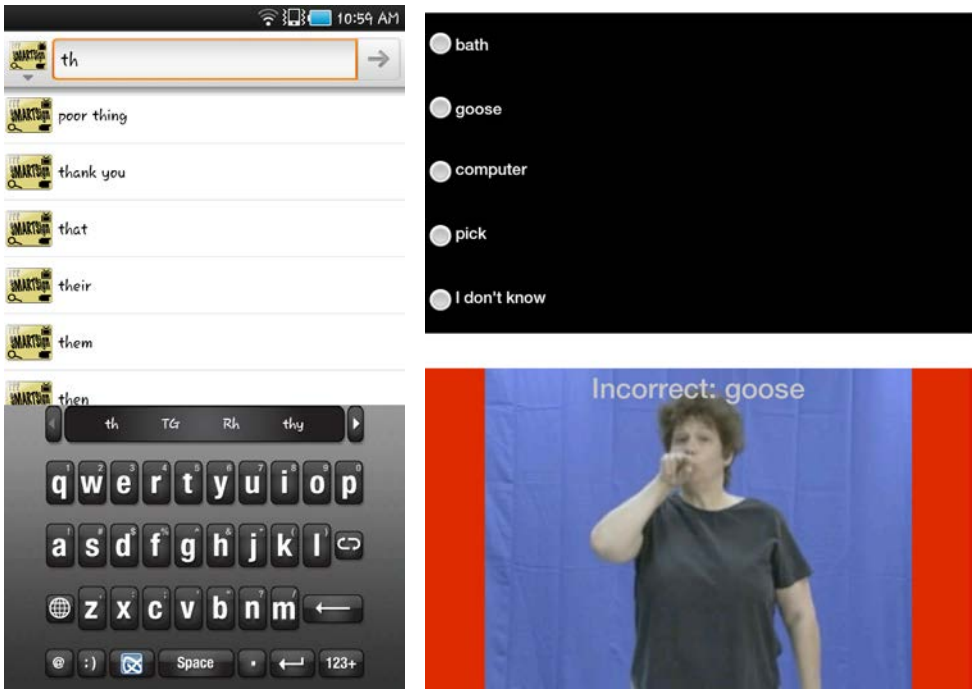
4.6.1 Current Components

The prototype of SMARTSign has three components focused on ASL vocabulary acquisition. These components are:

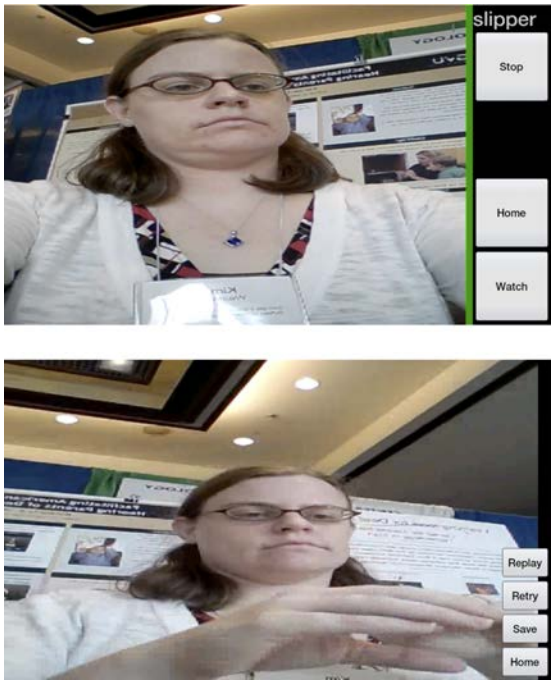
- SEARCH - allows parents to search for and watch ASL videos by typing or saying the associated English word.
- STUDY - gives parents the chance to learn new vocabulary through a quiz-based interface.
- RECORDER - takes advantage of a device's front-facing camera to provide parents with the ability to record themselves signing and compare with the source video.

These components are shown in Figure 15. The application is designed to function as much as possible without the need for an active Internet connection.

Parents reacted positively to all three components and to the system as a whole. Parents viewed the system not just as a tool for them to learn ASL, but something their whole family, including siblings and extended family, could use to learn. Two



(a) Search (b) Study



(c) Recorder

Figure 15: The three SMARTSign components

parents talked about how the interface was easy for them to use and understand. Two parents commented on the quality of the videos and how easy it was to see the motion in them. One mother said it was a good system for people without access to classes. Two parents expressed the sentiment that it would have been good for them when they started learning "and now too."

Although nothing negative was said about the SEARCH component, the search functionality had the least amount of positive reactions (six of the ten families). This lack of reaction may be due to the fact that basic search functionality is something that parents are familiar with on the Internet and with books. One mother mentioned the desire to incorporate English phrases. She noted that sometimes only "one sign is needed to convey four English words" as in English idioms and some negated signs like DON'T-LIKE. The mother who used Yahoo! as her primary source for new sign information liked SEARCH because it was a lot faster than using the Internet and because you could just type in a few letters to get the sign instead of the whole word.

The first participant made a number of useful suggestions that led to the positive reception of the STUDY component by the rest of the participants. Her original impression was that STUDY was useful for practicing vocabulary that had been learned elsewhere but did not have value in discovering new vocabulary. She suggested that when parents selected an incorrect English word they should be shown the video of the sign they selected. This modification to the original system was appreciated by two of the later participants. One of the participants said that guessing the signs would help them learn. One of the parents appreciated the STUDY component because reception of signs was the hardest thing for him to master.

Parents seemed the most impressed with the RECORDER component of SMART-Sign. One mother said that in her class they were asked to record themselves signing, so it was really useful to incorporate the recording mode to help people perfect what they are doing. Another parent was impressed with the opportunity to compare his

signs with the example sign. He did stipulate that he tended towards being over-exacting. One mother thought that the RECORDER component might be useful for her child, who liked to act out movies. A number of interesting applications were discussed. Because it is possible to record anything, other suggestions that arose from the interviews included recording stories for their children in sign and leaving messages. One parent asked if the system could evaluate the signs. Although a desirable addition, sign recognition is beyond the current capabilities of the system.

4.6.2 Proposed Additions

Four potential extensions were described to the parents to obtain feedback. These extensions are aimed at helping parents advance past simple vocabulary acquisition and help them to learn grammar and fluency. The extensions discussed were

- *Reading a story* - Organizing learning material around helping parents learn to sign a children's story book.
- *Grammar* - Information about the grammatical structure of ASL.
- *Deaf culture* - Information about the history of the Deaf community as well as advice on how to interact with members of the Deaf community. The birth of a deaf child is usually the first experience a hearing parent has with deafness. By providing parents information about the Deaf community and culture, parents may be less nervous about approaching Deaf adults and will gain more opportunities to practice their ASL.
- *Communication advice* - Information on how to attract their child's attention and make sure they are communicating effectively. Parents with hearing children can point to something and talk about it using the visual and auditory channels. Because the visual channel is also the channel of communication for deaf children, parents need to be more aware of their child's focus of attention.

The extension that seemed most exciting to parents involved teaching vocabulary and grammar with the goal of learning how to read a story to their children. All ten parents expressed interest in this capability. Two parents also suggested nursery rhymes. One mother talked about wanting to read Bible stories to her child but not having access to anything at the appropriate level. Another mother said that a dialogue with someone talking and asking you to answer a question which you could record might be useful as well. Parents were very interested in a system that would help them with their production skills and improve fluency.

Small grammar lessons were less interesting to the parents. One mother said that they are important, but she did not feel parents would use them because it might make it feel too much like school. Others said it would be great to know or be useful information.

Deaf culture lessons received even more mixed reactions. Two parents stated explicitly that they were not interested in Deaf culture tips. One said it would be more useful for Deaf families. A third person was unsure of their usefulness. She was not interested in general Deaf culture, but she was interested in information about politeness when interacting with Deaf adults. She wondered whether it was rude to approach two signing adults you did not know and whether it was rude to watch people signing in the same way it would be rude to listen in on someone else's conversation.

Five parents were in favor of Deaf culture lessons. Three of them said that they did not know anything so any information was good. One parent said as long what was being shown was understandable, the Deaf culture lessons would be interesting. The comment about understandability led to a discussion of how to present information. Parents liked the idea of signed video lessons with subtitles, but wanted to see more than just a direct English translation in the subtitles. Parents liked the idea of subtitles with a literal transcription from the sign glosses so they could understand

the grammar and vocabulary in the videos. One mother provided suggestions for these lessons. She thought it would be interesting to give information about technology for the Deaf such as lights that flash when the doorbell rings. She emphasized that for these tips to be useful they needed to be really "parent friendly."

Parents were also asked about their interest in lessons with advice for helping them communicate with their child. Half of the parents were interested in these lessons. Two parents said that they have known for many years about their child's hearing status, and they still did not know anything. Another parent said that this would especially be useful for parents whose children had recently been diagnosed. One parent said that he was not interested in interaction lessons because early intervention had done a good job telling him the information he needed. Two parents suggested potential lessons. One mother talked about getting her child's attention, and another talked about reminding herself to sign.

4.7 Phone Ownership

The next phase of the SMARTSign application development involves deploying software for parents to use in their daily life, therefore the last portion of the interview was intended to learn about current technology ownership. Four of the parents already owned smart phones. Five parents also paid for monthly data plans. All of the parents were willing to switch phones in order to be able to use the SMARTSign application.

Parents provided valuable information about what was important to them in a phone. Two mothers were really interested in the devices with front-facing cameras. One mother said that since her son is getting older, he will start going out alone to play with friends. If she wants to be able to communicate with him, ASL would be the most convenient. Phones also serve an added bonus as entertainment for their children while waiting. Doctors' offices do not usually activate captioning on their

TV, so mothers can give their phones to their children to play games as entertainment. Parents are also excited about potential educational opportunities for their child that can be provided by smart phones. Parents noted the convenience of having access to SMARTSign on a mobile phone. As one mother said she would be able to use the software anywhere: "public, home, library, shopping." She said she would probably be on the phone all of the time.

4.8 Discussion

We interviewed hearing parents from ten different families who had deaf children to better understand their needs when learning ASL. Based on what we learned about parental motivation, the main aim of our tool should be providing assistance to increase parent-child communication.

4.8.1 Creating an Ideal Learning Tool

Looking at the reactions to the various learning tools discussed in the interviews, we can gain an impression of the characteristics that make a successful or unsuccessful learning tool. Classes and Early Interventions share the traits of being regularly scheduled and interactive, but Early Interventions received more positive reactions. One reason for the positive comments is the fact that Early Interventions are more individualized than classes and very specific to the needs of an individual parent and child. A successful intervention should focus on the specific needs of hearing parents and should not focus on general ASL learning. This aim is also reflected in comments parents made about classes not focusing on what was important for them to learn to satisfy their immediate needs. Learning material needs to be as relevant as possible to reducing the communication gap.

Another characteristic of learning tools that lead to more positive reactions is dynamic presentation of signs in the form of videos instead of static images. DVDs, websites, and mobile phones all shared this trait. Websites and mobile phone users

had similar response patterns, which is consistent with the fact that parents used their mobile phones to access the websites and not standalone applications. DVDs had more positive reactions, perhaps due to the fact that they are usually designed around themes and accessible to whole family. Books, which present static images, are not desirable.

A learning tool should not focus solely on vocabulary. The exclusive vocabulary focus was a commonly stated negative of many of the learning tools: DVDs, websites, and books. While the current version of SMARTSign does only focus on vocabulary, we hope that with the addition of some of our proposed components we can help parents improve not only their vocabulary ability but also their fluency and understanding of the ASL language as a whole.

4.8.2 Improving SMARTSign

Parents were generally satisfied with all three of the existing SMARTSign components, so the discussion here will focus mainly on the four suggested additions. The parents we interviewed were unanimously in favor of a tool that focused on providing grammar and vocabulary associated with reading a story to their children. This desire aligns with a number of characteristics noted in the previous section. One of the biggest advantages is the focus on more than just vocabulary. Story telling would also be, by definition, interactive because it would require the parents to produce the signs in order to tell the story to their child. It also fulfills an immediate need that parents said they had. Many parents talked about their desire to read stories to their children, and the lack of opportunities to do so even before this addition was mentioned.

The remaining three additions: lessons on grammar, Deaf culture, and interaction strategies received equally mixed reactions. The varying responses towards these additions creates an opportunity for parents to customize their experience. Parents will be able to adjust their preferences for receiving these lessons so they can get the

information that is most relevant to them.

4.9 Conclusion

Hearing parents' desire to learn ASL is based not on mastery of the language for its own sake, but to fulfill a specific need of improving communication with their child. The parents we interviewed expressed strong motivation to learn and use ASL more, but they still only experience limited success. The focus of SMARTSign will not be on convincing parents of the necessity to learn ASL, but in providing parents with the appropriate tools to help them gain more experience with a difficult language.

Initial reactions to the prototype system aimed at vocabulary acquisition were positive. The next step in this research will be to evaluate a method for presenting vocabulary lessons to parents on their mobile phones through an in-the-wild study. This evaluation helped inform a second study which will be described in Chapter 6. In this study, I compare two different motivators for learning ASL vocabulary. In one condition lessons are based on aiding parents learning to read stories in ASL to their children, which was found to be the most compelling motivator for increasing fluency and grammar ability. Through this research I hope to increase hearing parents' ASL language skills and communication ability with their child. With hearing parents better able to communicate with their child in an accessible language, I hope to reduce the language gap between deaf children of hearing parents and other children their age.

CHAPTER V

THE SMARTSIGN APPLICATION

5.1 Introduction

SMARTSign is a stand-alone mobile application designed for phones running the Android OS. While a version for the iOS is planned, it has not yet been implemented. The primary focus of the application is vocabulary acquisition. As discussed in Sections 2.4.1 and 2.6, SMARTSign was designed to accommodate both the "push" and "pull" paradigms to provide opportunities for learning. In this chapter I describe design of the SMARTSign application. SMARTSign consists of three main components: Search, Study, and Recorder.

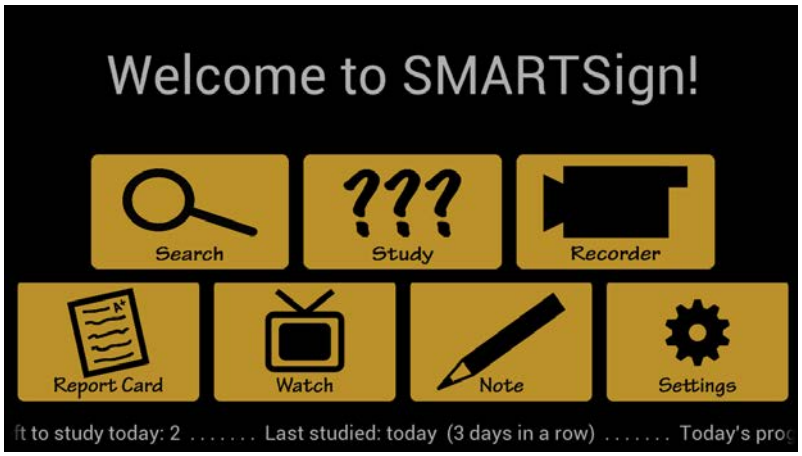


Figure 16: The application Home screen

Figure 16 shows the application Home screen. The top row of buttons allows access to the three main components for learning. The bottom row of buttons is for auxiliary functions: reviewing progress in the Report Card, watching recorded videos, providing feedback about the application and changing application settings. At the bottom of the screen, a scrolling text marquee displays access information: how

many words still need to be studied for the day, when last used STUDY, SEARCH, and RECORDER and how many days they have used each component consecutively.

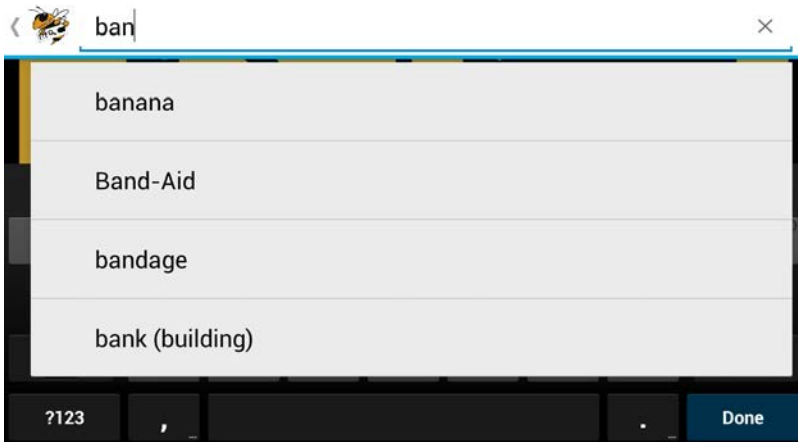
5.2 Search*: In-Context Learning*

The SEARCH component of SMARTSign allows learners to search for an ASL video based on related English terms. The search functionality is useful for learners who are trying to communicate in ASL and need assistance remembering the sign for a particular word. The SEARCH component provides one method for learners to "pull" learning content when they want to learn and functions like a dictionary. This component design originates from a pilot deployment of a system called SIGNKICK.

SIGNKICK was essentially an ASL dictionary on an ultra-mobile PC. Typing in an English phrase would provide the ASL equivalent in a video. It was given to hearing parents with deaf children with the assumption that parents would look up a word and show the sign video to their children. Instead of showing the device to their children, parents in the study practiced the sign from the video until they could use it with their children. This study was an early indication that hearing parents did want to learn ASL, but were just lacking in resources to do so properly.

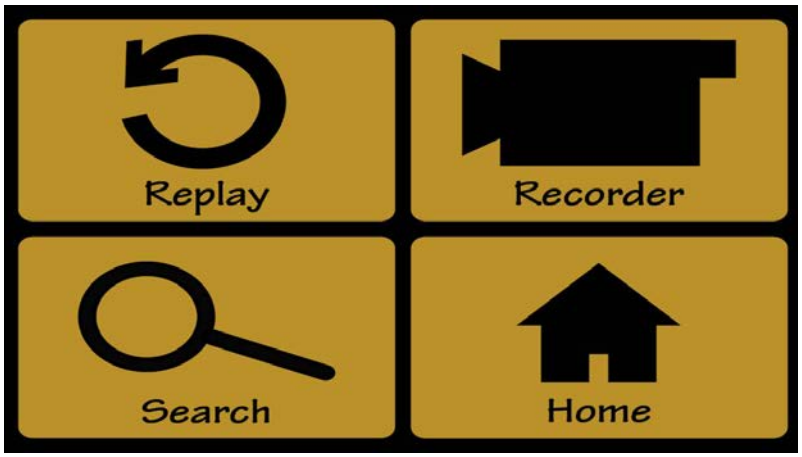
In the current implementation of SMARTSign, learners can search for words either through typing on the device's keyboard or by speaking into the phone. Voice search is enabled through Google Voice and thus requires network access. It is not necessary to know the exact spelling of the word. Typing in partial searches will return all words that contain the typed characters. As the learner begins typing, the system starts suggesting potential matches from the database of signs.

For example, in Figure 17(a) all signs containing the characters 'ban' are displayed. Once the learner has selected a word, the corresponding video is shown. The English word is displayed as an overlay on the video. In Figure 17(b) the learner has selected the word "banana." After the video finishes playing, the learner is taken to the



(a) Searching inside the application

(b) The appropriate video is displayed with English equivalent



(c) SEARCH navigation screen

Figure 17: SEARCH in SMARTSign

navigation screen shown in Figure 17(c). The learner has the option to REPLAY the video of the current sign (the looped arrow button), go to the RECORDER component to practice performing the current sign (the video camera button), perform a new SEARCH (the magnifying glass button), or return to the HOME screen (the house button). The RECORDER component will be described in detail in Section 5.4.

Two goals of the application design are quick access to features and opportunities for learners to gain access to new signs. To this end, SMARTSign allows searching of its database of signs from the phone's main screen outside of the SMARTSign application. This feature enables learners to search without first entering the application and navigating menus, eliminating steps. New signs can then be discovered during the course of normal web search. Figure 18 shows what SEARCH looks like from the phone's main screen. Here the learner is typing in the letters 'an.' The search results display suggestions from the Internet as well as from SMARTSign. Selecting one of the suggested words will activate the application and display the video along with the English word.

5.3 Study*: Learning During Free Time*

Learners will not always have a particular term in mind, but SMARTSign also enables discovery of new vocabulary terms. The STUDY component of SMARTSign is intended to fulfill this function. The STUDY design is based on the idea that learners can access the SMARTSign application and acquire new vocabulary during free moments during the day. STUDY takes the form of a quiz-based interface.

The role of using a quiz to learn ASL on mobile devices was explored by Henderson-Summet [43]. The basic interaction paradigm is that a video with an ASL sign is shown and immediately followed by a screen with multiple choice responses which can be selected with a radio button. Figure 19 shows the two main views in this sequence. In Figure 19(a), the target video is being played. After the video is done

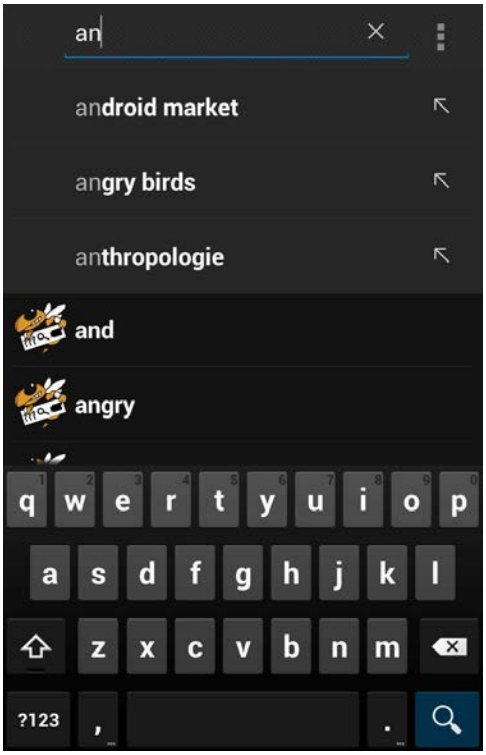


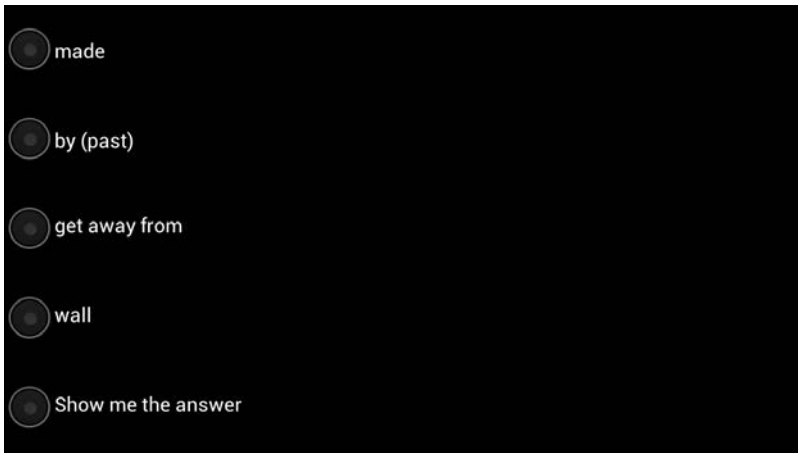
Figure 18: Searching outside the application with word suggestions

playing, Figure 19(b) is shown. One of the choices is the correct English equivalent and three are incorrect choices. The bottom choice "Show me the answer" is for when the learner does not know the answer and does not want to guess.

The original SMARTSign implementation has been altered from Henderson-Summet's design at the suggestion of members of our target population who reported feeling frustrated at not feeling like they were learning when the got the response incorrect. In the original implementation, the learner would simply be told whether they were correct or incorrect. The current SMARTSign application has three different responses based on the learner's choice:

- *Correct*
- *Incorrect*
- *"Show me the answer"*

(a) An ASL video is displayed



(b) Screen with five choices

Figure 19: Learning new signs with STUDY

These responses are shown in Figure 20. All three responses are based on the signs and choices given in Figure 19. The sign in Figure 19(a) is the prompt. If the parent chooses "get away from" as the response, then they would be shown Figure 20(a). The background has been turned to green to indicate correctness. The text above the video also says "correct" and provides the English word along with the video. If the parent selected "wall", they would be shown 20(b). The background is red to indicate that the response was incorrect. The text says incorrect and target video is shown again, as in Figure19(a). This way the parent has another chance to see the sign. If the parent gives up and selects "Show me the answer", then they

(a) The choice was correct

(b) The choice was incorrect

(c) The learner chose to see the answer

Figure 20: System responses in STUDY

Figure 21: The STUDY navigation screen

will be shown the video and the correct English word as shown in Figure 20(c). We do not want learners to become frustrated when there are signs that they have not learned yet.

After getting the word correct or having selected "Show me the answer," the learner will be taken to the navigation screen shown in Figure 21. Clicking on the double arrows will provide the learner with a new video sign to learn in STUDY. Selecting the video camera will activate the RECORDER component (to be described in Section 5.4). The learner has the option to REPLAY the video for a current sign with the looped arrow button. The house button will return the learner to the HOME screen. At the top of the screen is a scrolling text marquee. In the text, the learner is shown their study progress for the day: how many words they still need to study, a break down of how many words were new versus review, and the nature of the review, whether it was the quiz or a recording. REVIEW will be described in detail in Section 5.5.

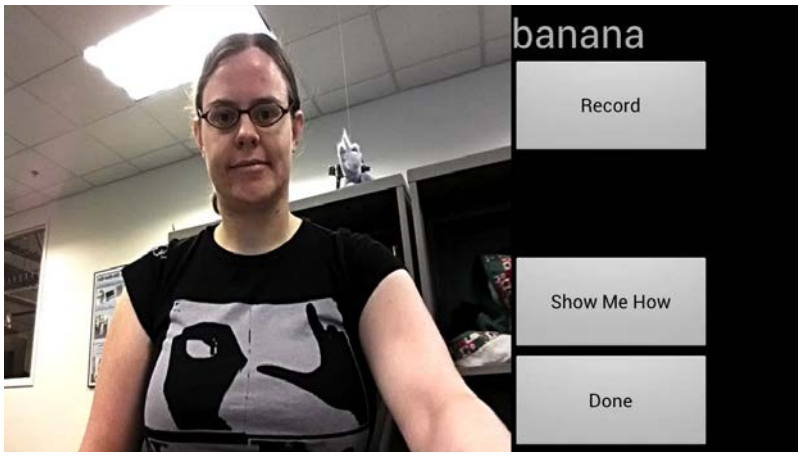
5.4 Recorder*: Practicing Sign Production*

One thing with which parents have reported difficulty is practicing their signs enough to be comfortable to produce them without worrying about being "wrong" or looking silly. The RECORDER component of SMARTSign allows the learners to record themselves signing a word or phrase and then replay and save those videos on their phone using a front-facing camera. Learners can activate a practice session through SEARCH or STUDY (as shown in the previous sections) via their respective navigation screens. These recording sessions would be targeted at a specific word.

Figure 22 shows the general recording mechanism. Notice the word "banana" in the upper right corner of the screen. The target sign the parent should be signing is BANANA. The same button is used to both start and stop recording. After pressing the "Record" button, the text changes to say "Stop."

After a video is recorded, it will be immediately replayed as seen in Figure 23(a). When returned to the recording interface, shown in Figure 23(b), there is a new button that says "My Video." Pressing this button will replay the recorded video. If the learner needs help remembering how to sign the word, they can select the "Show Me How" button at any time. This will replay the source video as shown in Figure 23(c). The learner can re-record, view the recording, and watch the example video as many times as they feel necessary. When they are done, they select the "Done" button and the last recorded video will be saved automatically.

If RECORDER has been activated directly from the HOME screen, not STUDY or SEARCH, then there is no target word and no button for "Show Me How." In this situation, when "Done" is selected, the learners are sent to the SAVE screen where they will be prompted to enter a file name. This interface is shown in Figure 24.



(a) Before recording has been activated

(b) Video is being recorded

Figure 22: The RECORDER interface

5.5 Study*: Reviewing Previously Seen Vocabulary*

In Section 5.3, the component for studying new vocabulary was described. After the learner has finished studying all of the new vocabulary for the day, continuing access to the STUDY component will provide them the opportunity to review previously learned signs. Participants will know they are in REVIEW mode because it says "Review" in a text overlay on the video as seen in Figure 25. Emphasis is placed first on words that received incorrect responses the last time they were seen, then words for which the correct response rate is less than 70%. If the sign chosen by the application received a correct response the last time it was seen, there is a 50% chance that instead of

(a) Viewing the recorded video

(b) After recording

(c) Viewing the source video

Figure 23: Evaluating a recording

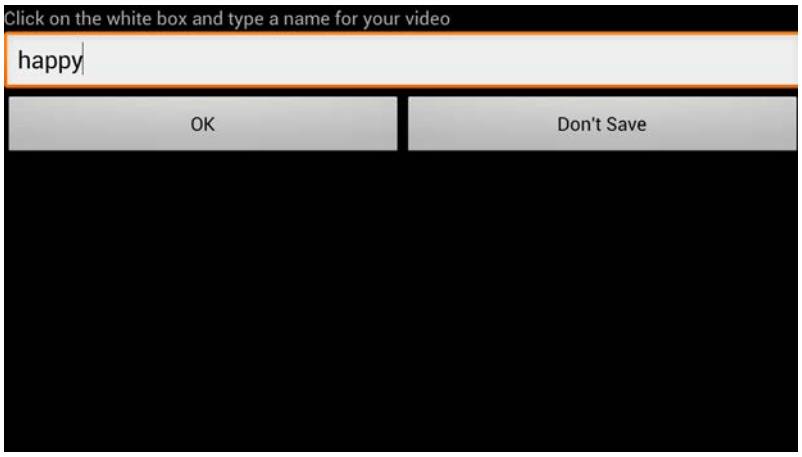


Figure 24: The RECORDER save interface

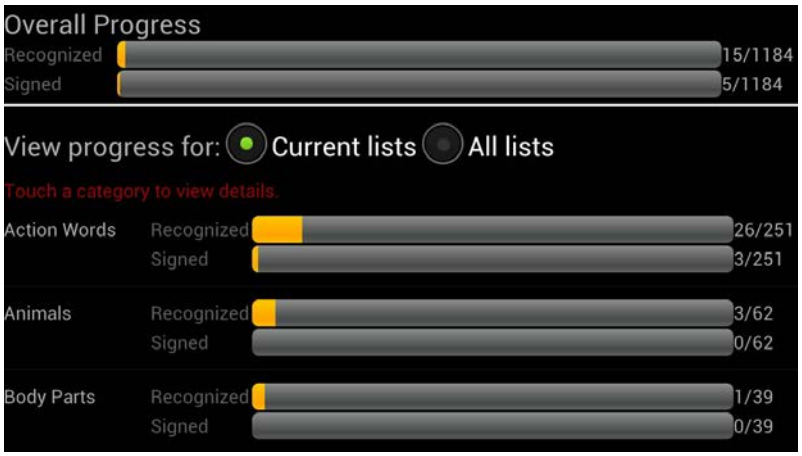
Figure 25: Video when reviewing signs

using the quiz to review the sign, the learner will be sent to the recording interface to practice signing. Early pilot studies indicated that without enforcing use of the RECORDER component in some manner, participants largely ignored it.

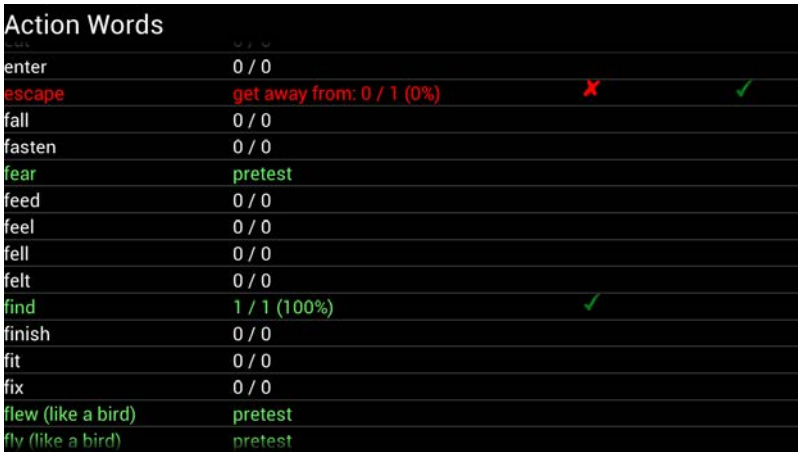
5.6 Report Card

The purpose of the REPORT CARD is to help learners keep track of progress. It shows signs they have learned and signs they might want to practice further. In the REPORT CARD component, information is displayed in two ways. The first view is the OVERVIEW screen shown in Figure 26(a). On the OVERVIEW SCREEN, learners can see their progress learning to recognize and sign all of the words in

the SMARTSign database, currently 1,183 unique English words representing 933 unique ASL signs. They can also view their progress learning the words in specific categories. For example, in Figure 26(a) this learner can recognize 26 "Action Words" in the database but has only practiced signing three of them.



(a) Overview screen



(b) Detail screen

Figure 26: The Report Card component

Selecting a category causes a Detail view for that category to be displayed such as Figure 26(b). In this figure, the Detail view for the "Action Words" category is shown. The Detail view shows progress learning individual words in the selected category. In Figure 26(b), the learner has recognized the word "find." For the word "escape" which has the same sign as get away from, the learner has seen the sign once

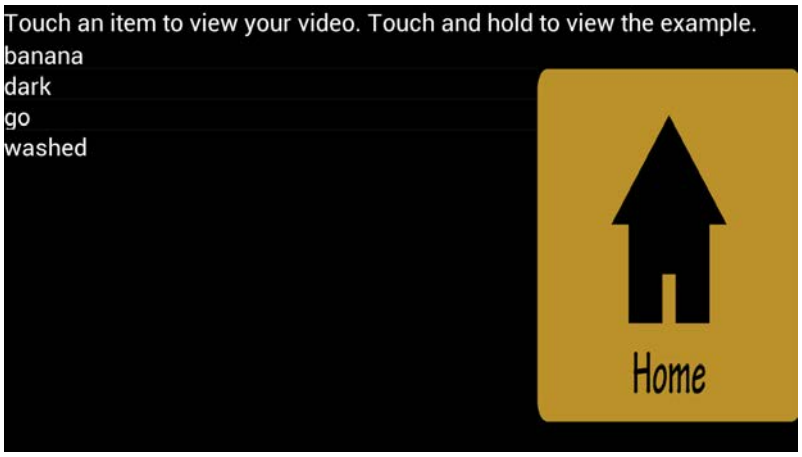
but not gotten it correct. The learner has recorded herself signing the phrase. The text is red because the learner's correct response rate is less than 65%. As the learner correctly recognizes a sign, the color changes from red to yellow (less than 75%), and then to green (greater than 75%). White text indicates that the learner has not yet seen that sign. The colors are intended to alert the learner to signs that may need more practice. The word "fear" is green but has no statistics. The accompanying text says "pretest," indicating that this sign was guessed correctly in a pretest. It is assumed that the participant already knows this sign.

5.7 Watch

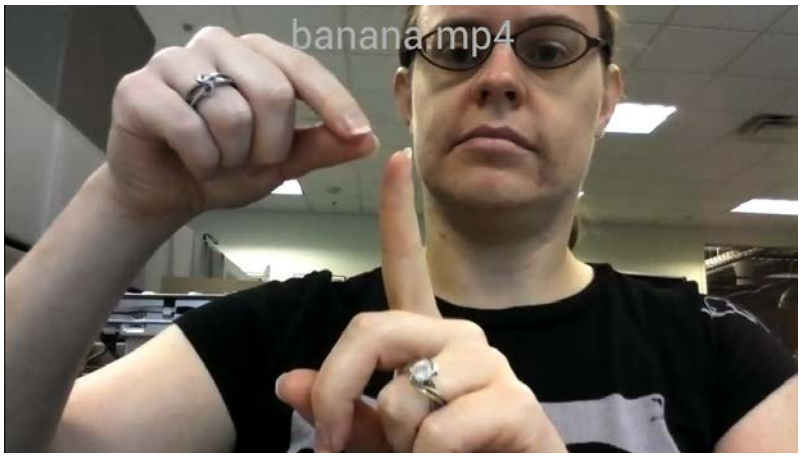
The WATCH component allows learners to review their recorded videos. The interface for the WATCH component is shown in Figure 27. When entering the WATCH component, the learner is shown a list of all of the available videos, shown in Figure 27(a). Only the most recently recorded video for each sign is available. If the learner taps on a word, they will be shown the video they recorded. In Figure 27(b), the learner has selected the recorded video for "banana." If the learner taps and holds their finger on a word in the VIDEO LIST, they will see the example video provided throughout the rest of the application for comparison.

5.8 Note

The NOTE component was designed to allow users of the application to communicate and leave messages for development purposes or for study-relevant communication. Learners can create either a text or a voice note depending on which method fits circumstance in the moment. The interface for the NOTE component is shown in Figure 28. Upon selecting the NOTE component, learners are shown the screen in Figure 28(a). They are presented with the choice of creating a voice note or typing into the text box. If they select the option to create a voice note, the application starts recording immediately. As they are recording, they are shown the screen in Figure



(a) Video List screen



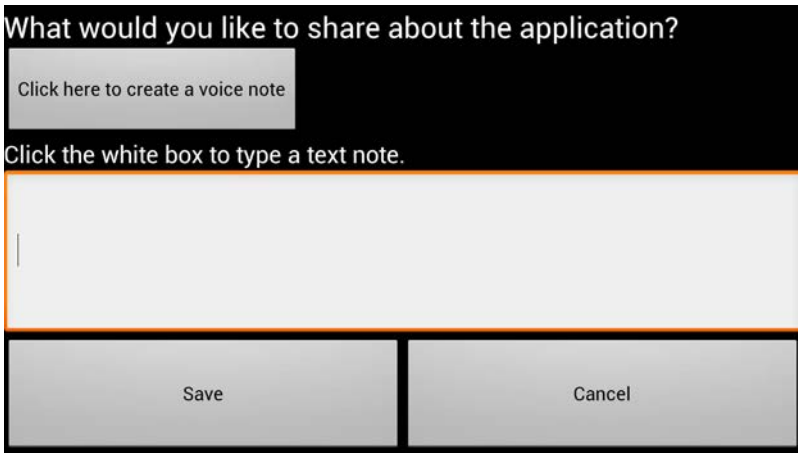
(b) Video playback

Figure 27: The Watch component

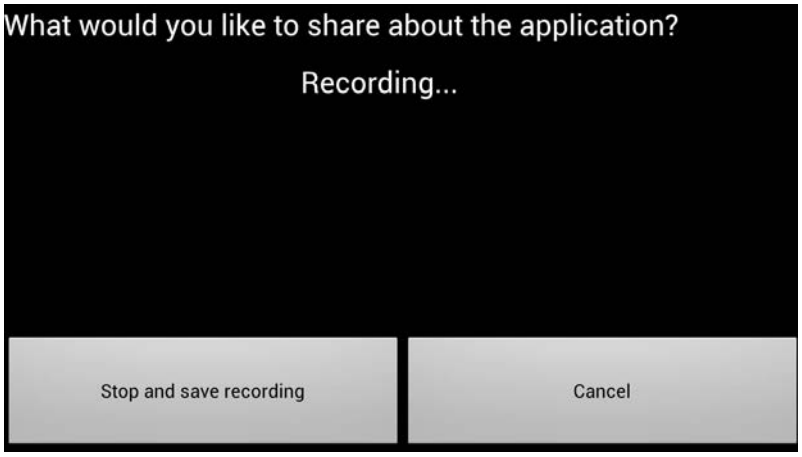
28(b). They can either save the recording or cancel, which will delete the recording. If they start typing, the interface looks like Figure 28(c) as they are creating the message.

5.9 Settings

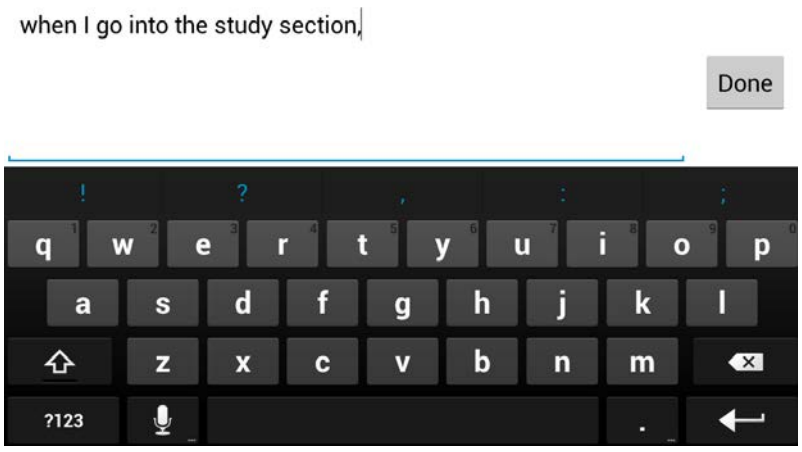
I designed flexibility into the application through user customizable settings. All of the settings are shown in Figure 29. The two categories of adjustable settings are Notifications and Vocabulary. Users can specify whether or not they want notifications, which days of the week they would like to receive reminders and at what time they would like to receive the reminders. These options are shown in



(a) The main screen

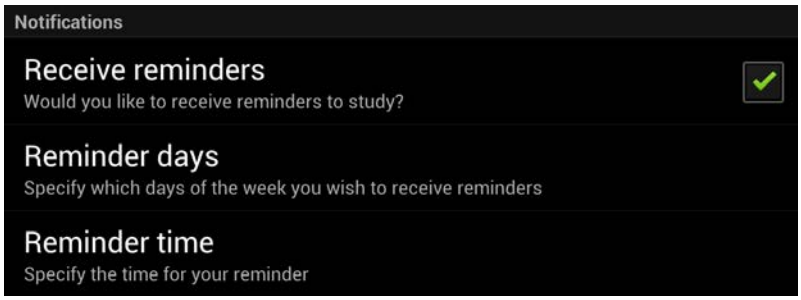


(b) Recording a voice note

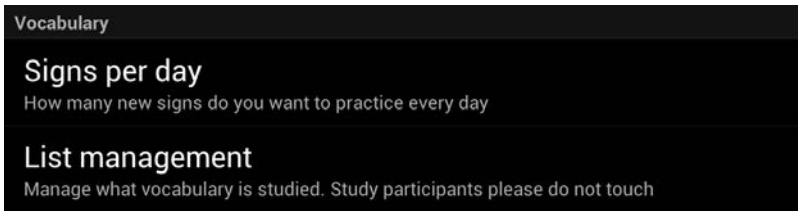


(c) Creating a text note

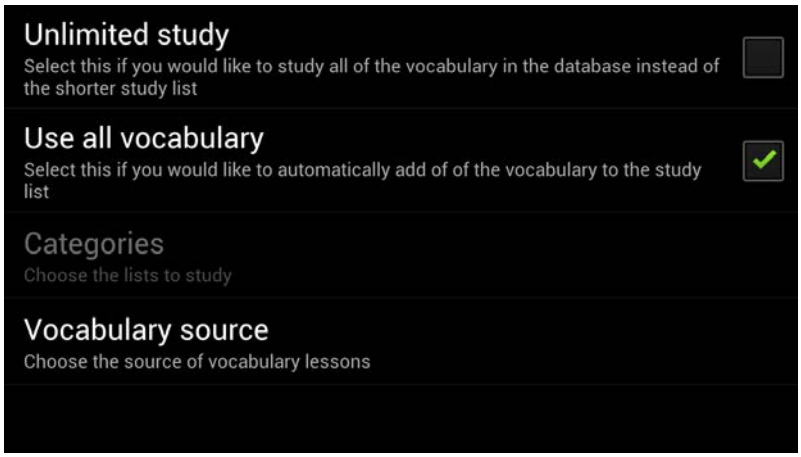
Figure 28: The NOTE component



(a) Settings options for notifications



(b) Basic vocabulary control



(c) Advanced vocabulary control

Figure 29: The Settings component

Figure 29(a).

Figure 30 shows the appearance of the full notification that users receive. When a notification is activated, the clock icon appears in the upper left corner of their device. Dragging the top bar to view the notifications reveals the full text as shown in Figure 30. Clicking on the notification will direct the user to the home screen of the SMARTSign application. The notification will be deactivated once the user starts to study. The notification only appears if the user has not yet studied the entire scheduled set of words for the day. If the user has already studied that day,

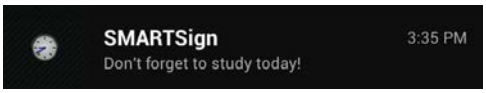


Figure 30: The notification users receive to remind them to study

then they will not receive the reminder.

NOTIFICATIONS provide "push" delivery of learning content. As discussed in Section 2.4, "push" delivery is a common feature of many mobile language learning systems. However, because SMARTSign is not designed as a tool to support classroom curriculum, it is unknown how parents will respond to notifications to study. Li et al. established that to fully take advantage of the "anytime, anywhere" affordances of mobile phones, learning systems need to accommodate "push" and "pull" lesson delivery [66]. SMARTSign accommodates both paradigms by allowing learners to access the three main components of SMARTSign: SEARCH, STUDY, and RECORDER whenever they wish, even when they not prompted by a notification.

VOCABULARY settings are shown in Figure 29(b). The main VOCABULARY setting allows the learners to choose how many words they would like to study daily. Learners can choose any between four and ten words to study daily. They also have the option to set no limit. Choosing this option might be more desirable at the beginning when the studied vocabulary list is still small and review is repetitive.

The other VOCABULARY settings, hidden under the "List management" heading, are used to control which portions of the database are accessible for study. These settings are shown in Figure 29(c). The "Unlimited study" option toggles whether a limited subset of words are accessible to study (as determined by an auxiliary application) or the entire database. If "Use all vocabulary" option is selected, then all of the available words in all available word categories are automatically added to the list of words to study. If it is not selected then the user has the ability to select a subset of categories to focus on with the Categories option. In Figure 29(c) the Categories option is disabled because "Use all vocabulary" has been selected. The

VOCABULARY SOURCE option allows users to toggle between organizing the words to study by Word Types or by children's books (Stories) that contain the vocabulary words.

5.10 Supported Devices

SMARTSign was created to work on the Android operating system. It has been tested on a variety of devices. It was originally developed for the Motorola DROID and has also been tested on the Droid Incredible. Although the RECORDER component, is functional on these phones, it does not perform ideally because of their lack of front-facing cameras. Users are not able to see themselves while signing.

SMARTSign is ideal for phones and devices with front-facing cameras. Early working systems have been developed for the Motorola Backflip and HTC EVO. For demonstration purposes, SMARTSign also runs on the Samsung Galaxy seven and ten inch tablets which have a larger form factor. The current version of SMARTSign has been optimized to run on the Android 4.0 Ice Cream Sandwich operating system. Devices capable of using this operating system include the Samsung Galaxy Nexus from Verizon Wireless and the Samsung Nexus S from AT&T and T-Mobile.

Phones with front-facing cameras are becoming more prevalent among hearing parents with deaf children. The advent of programs like FaceTime which can enable real-time ASL conversations between parents and their children makes phones with front-facing cameras more desirable. As stated by one mother in Chapter 4, as her son gets older and starts going out on his own, she wants a phone that enables easy communication between them.

5.11 Vocabulary Selection

The vocabulary for SMARTSign is based on the MacArthur-Bates Communicative Development Index (M-BCDI)[5, 32]. The M-BCDI is an index of words that children should know and/or recognize from birth to three years. The index has also been

validated for ASL [5]. The SMARTSign application incorporates both the English and ASL indices. The database contains 933 unique ASL videos which correspond to 1,183 English words. Obvious words that do not have an ASL equivalent, such as animal sounds, were omitted. When the learner studies vocabulary from children's books 479 unique sign videos representing 582 English words are accessible. The book vocabulary is a subset of the vocabulary available when studying based on "Word types." Complete lists of all of the vocabulary available in the dictionary are shown sorted by Word Type and by Story in Appendix C and Appendix D respectively.

CHAPTER VI

STUDY OF PARENTAL VOCABULARY ACQUISITION THROUGH SMARTSIGN

6.1 Introduction

This chapter describes a deployment of SMARTSign to hearing parents with young deaf children. The purpose of this study was to explore how parents used a mobile application for learning vocabulary. In the study, I measured the effect of presenting vocabulary in two different conditions. In one condition, participants learned ASL vocabulary for popular children's stories. In the other condition, participants learned ASL vocabulary organized by vocabulary themes. Because parents from the interview study described in Chapter 4 were so positive about the idea of organizing learning around stories, I hypothesized that participants learning ASL vocabulary for children's stories would learn more than participants in the theme condition.

6.2 Participant Recruitment

Ten participants, including four pairs of parents and two mothers, representing six households, were recruited. All participants were residents of Texas, living in the Austin or San Antonio area. A map of participants' general locations is shown in Figure 31. Pins are located at the geographic center of the participants' town of residence. Participants were recruited from posts on the Texas Hands & Voices Facebook page, signs posted at the Texas Statewide Conference for the Education of the Deaf and Hard of Hearing, and emails and signs distributed by a Parent Infant Program teacher at the Texas School for the Deaf.

Table 5 shows the basic demographic information for all of the participants and

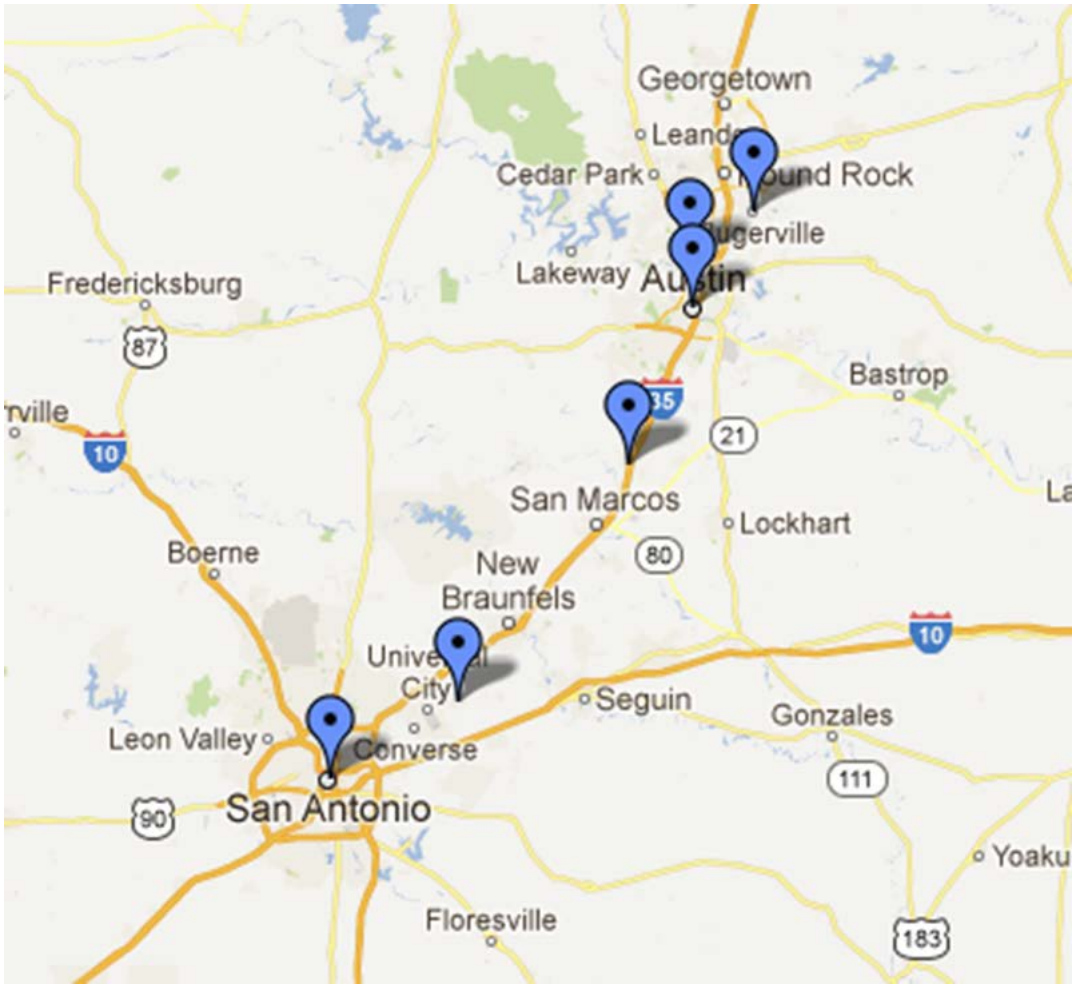


Figure 31: Map of participant locations

their deaf children. There were four males and six females, with ages ranging from 21 to 46 years ($M = 31.1, SD = 8.6$). In four of the families, the deaf child was an only child. The ages of the deaf children ranged from 19 months to four years ($M = 2.8$ years, $SD = 1.0$). The age at which the deaf child was first identified as deaf ranged from birth to 24 months ($M = 9.5$ months, $SD = 11.4$). Participants reported learning ASL for three months to three years ($M = 8.7$ months, $SD = 10.2$). Three participants were part of the Family Signs program at the Texas School for the Deaf. The Family Signs program pairs parents with an ASL instructor for half hour lessons once a week. The other participants did not describe their learning activities.

Table 5: Participant demographics

Family	**Participant**	**Age**	**Gender**	**Deaf Child**	**Child age**	**Age identified** (in months)	**Deaf family**	**Time learning ASL** (in months)
1	Orange	39	Male	only	2.5	24	No	3
	Gray	34	Female				No	
2	Green	46	Female	youngest of four	2	0	No	3
3	Black	35	Female	only	4	0	No	36
4	Tiedye	21	Female	only	3	3	No	12
	White	22	Male				No	
5	Ivory	25	Female	oldest of four	4	24	No	6
	Brown	24	Male				No	
6	Yellow	–	Female	youngest of two	19 mos.	6	No	3
	Purple	34	Male	only			No	

In the following sections, I describe basic information about the learning environments of the ten participants, divided by household. This information includes information about why they decided to learn ASL and what resources were available to them, as well as any observed uses of ASL at the beginning of the study. All participants were given unique color names. These names corresponded to the color of the background on the phone they were given, and the bag they were given to protect the phone and hold an instruction booklet for the application.

6.2.1 Family 1 - Mrs. Gray and Mr. Orange

Mrs. Gray and Mr. Orange are both medical doctors working the same field. They arrange their hours so that someone is always home for their deaf daughter who is an only child. They have been learning ASL for five months. They live in an area where there is only an oral school for deaf children. They intend to move closer to Austin where there are support services and classes in ASL for their child. Mrs. Gray reported being uncomfortable with technology and was excited by the number of signs she already knew.

6.2.2 Family 2 - Mrs. Green

Mrs. Green is a a medical professional. Her husband, Mr. Green, was present for all of the research sessions, but declined to participate in the study. Mrs. Green also lives in an area without local resources for ASL. She takes an online class through the Texas School for the Deaf in which she receives one-on-one instruction through video chat with a Deaf adult. She shares the signs she learns with her husband. While Mr. Green did not enroll in the study, he would ask Mrs. Green to teach him the signs when he saw her practicing with the phone. He said he did not want to join the study because he was not comfortable using the technology. Mrs. Green was very eager to learn ASL. She asked questions about different resources she could use and tried to learn as much as possible from the research team during our meetings.

6.2.3 Family 3 - Mrs. Black

Mrs. Black did not share much about her family, and we did not meet her deaf child. She and Mrs. Green are the two participants who did not have another person using SMARTSign in the house.

6.2.4 Family 4 - Mrs. Tiedye and Mr. White

Mrs. Tiedye and Mr. White were the youngest participants. During the first meeting they were teasing each other about who would learn more signs. While Mrs. Tiedye's system was being set up, Mr. White was already studying his first signs. During our visit to this household, Mrs. Tiedye was the one who was signing and disciplining their child. She would wave at her son to get him to pay attention to her. She would tell him to SIT and STOP. She also signed NO.

6.2.5 Family 5 - Mrs. Ivory and Mr. Brown

Mrs. Ivory and Mr. Brown had three children with one more born over the course of the study. Their oldest child, the only son, is deaf. Mr. Brown works from home and Mrs. Ivory is a stay-at-home mom. Mrs. Ivory said that at her son's school it is intimidating for hearing parents because pretty much everyone else is Deaf. At the first session, their son and oldest daughter were present. Mrs. Ivory remarked when her daughter pounded on the table to get her brother's attention. She pointed out that the daughter was picking up signs the fastest. The daughter signed colors to me, although she was signing BLUE for YELLOW. She also knew GREEN, RED, and ORANGE. She likes trains and signed TRAIN. The son was not signing as much. He did sign APPLE in the beginning. Mrs. Ivory was signing for him to SIT. He signed HELP at me when I asked him if he needed help using a paint program on a tablet.

6.2.6 Family 6 - Mrs. Yellow and Mr. Purple

Mrs. Yellow and Mr. Purple have the only child with cochlear implants. Mrs. Yellow is a stay-at-home mom. Mr. Purple has a Ph.D. in molecular biology. Their son is the youngest child in the study. During one of his meetings with the research team, Mr. Purple expressed disappointment with his son's progress with the cochlear implants. This disappointment was the reason that he decided to be part of the study and learn more ASL vocabulary. During the meetings with Mrs. Yellow and Mr. Purple we observed both parents interacting with their son. Mrs. Yellow and Mr. Purple mostly spoke to their son with occasional signs. Mrs. Yellow signed FINISH. The son signed MILK and HELLO. When the son signed MORE, the parents would give him some more food, so they are working to build the connection between signs and language. Mrs. Yellow and Mr. Purple also signed FOOD.

6.3 Experimental Design

Participants were divided into two groups. For the first group, the vocabulary they were given was organized around the different themes defined by the MacArthur-Bates Communicative Development Index [5]. See Appendix C for a complete list of relevant vocabulary. This condition will be called *Word Types*. For the second group, vocabulary was organized around stories the participants could read to their children such as "Go, Dog. Go!" by P.D. Eastman. The complete list of vocabulary sorted by book title is provided in Appendix D. This condition will be called *Stories*.

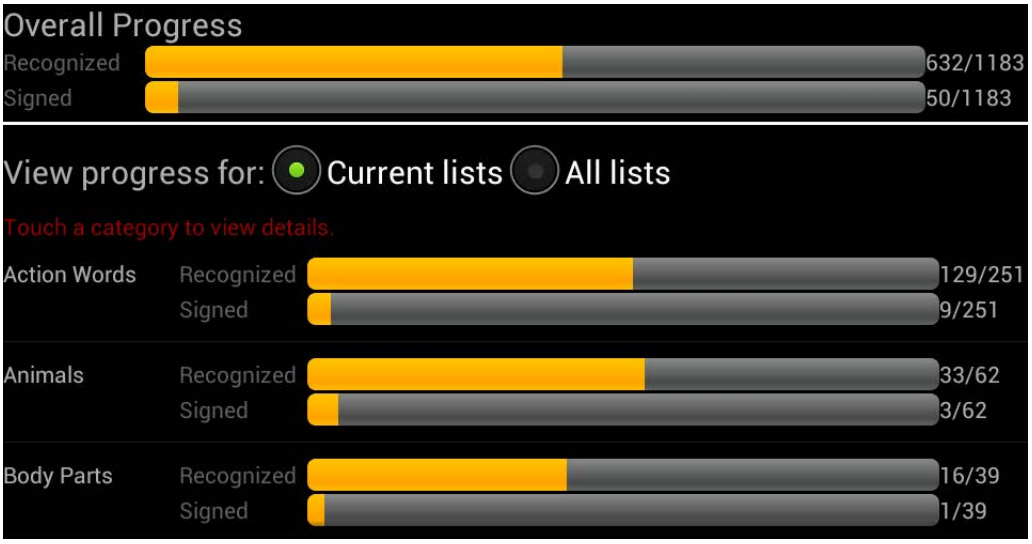
The selected stories are in English, therefore the target vocabulary consists of a transliteration of English words into ASL signs. When parents learn the vocabulary for the stories, they will not be able to sign the story in ASL; instead they will be able to sign the story using ASL signs in English word order. The advantage of choosing English stories is that parents are more likely to be familiar with them. However, by doing a transliteration, parents do not learn the complexities involved

with connecting signs in ASL. The parents will provide their children with more accessible linguistic input in the form of signs instead of spoken language, but they will not be communicating using a natural language such as ASL. Parents will not be learning true ASL, but the advantage of this method is that parents will be able to focus on learning the vocabulary and being comfortable performing the signs. Also, since the target population of parents have children who are less than three years old, single signs are all the children might be learning anyway.

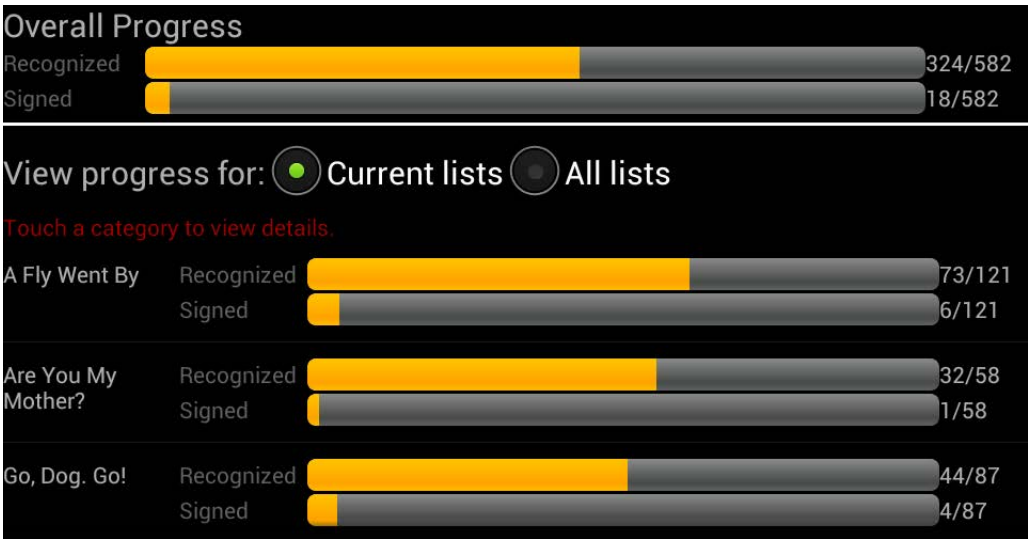
The list of potential vocabulary for both groups was the same, and only differed in presentation in the application as coming from a specific book or from the index of words in the Report Card component. Figure 32(a) shows how the Report Card would look to participants in the *Word Types* condition. Figure 32(b) shows how the Report Card would look to participants in the *Stories* condition.

This study recruited families where both parents were in the study and families where only one was. For families with both parents in the study, both parents had to be placed in the same condition. Otherwise the participants would discover that there were two different conditions. Deployment was balanced so that for each condition there were two households with two participants and one household with one participant. The number of males and females was also balanced. Participants' duration studying ASL was not controlled.

All participants were given a smartphone running Android 4.1.1. If the participant was on the AT&T or T-Mobile network, they received a Samsung Nexus S phone, shown in Figure 33(a). If the participant was on the Verizon network, they received a Samsung Galaxy Nexus phone, shown in Figure 33(b). Both phones have front-facing cameras which allow participants to record themselves signing. Participants were asked to use this phone as their primary phone for the duration of the study. They were asked to use the phone to study ASL vocabulary from the SMARTSign application for four weeks. Additionally, they were asked to study at least four times



(a) *Word Types*



(b) *Stories*

Figure 32: The Report Card Overview screen as it would appear to participants in the two conditions

every week to remain eligible to continue with the study.

(a) the Samsung Nexus S

(b) the Samsung Galaxy Nexus

Figure 33: The two phones used in the study

Participants were asked to set up an alarm in the application that would notify them when to study. Participants were allowed to choose which days of the week they wished to receive the notifications and at what time of day the notification should occur. They were asked to select at least four days per week for these notifications. Participants were also asked to select the number of new words to study every day. Once the participant learned all 80 new words, any subsequent access of the STUDY component would be review. Table 6 shows the preliminary settings for notifications and signs per day selected by the participants. Participants were encouraged to

Table 6: Participant settings

Family	Participant	Reminder Time	M	T	W	Th	F	Sa	Su	Signs per Day
1	Mr. Orange	9:00 PM	X	X	X	X	X	X	X	5
1	Mrs. Gray	9:00 AM	X		X		X		X	10
2	Mrs. Green	5:00 PM	X	X	X	X	X	X	X	10
3	Mrs. Black	11:00 AM	X	X	X	X	X	X	X	10
4	Mrs. Tiedye	1:00 PM	X	X	X	X	X	X	X	10
4	Mr. White	6:00 PM	X	X	X	X	X	X	X	5
5	Mrs. Ivory	1:00 PM	X	X	X	X	X	X	X	5
5	Mr. Brown	10:00 AM	X	X	X	X	X	X	X	10
6	Mrs. Yellow	10:00 AM		X	X	X	X			5
6	Mr. Purple	2:00 PM	X	X	X	X	X	X	X	8

contact the researchers at any time via phone or email if the application stopped working, or if they had difficulty or questions on how to use it.

Researchers met with the participants three times. The first meeting procedure was as follows:

1. Participants completed the consent form.

2. Participants filled out a pre-study questionnaire.

3. Participants took a pre-test to determine the vocabulary they would be learning for the duration of the study. The pre-test is explained in more detail in Section 6.4.3.

4. Participants were introduced to the features of the SMARTSign application.

All first meetings took place between October 1st and October 3rd, 2012.

The purpose of the second meeting was to download log data from the participants' phones. It also gave participants the opportunity to ask questions and the chance to leave the study if they wished. The second meetings with all participants occurred between October 16th and October 22nd, 2012.

At the end of four weeks, all participants were were sent an email that they were no longer required to use SMARTSign to study, but they could continue to do so if they

wished. The final meetings with participants were scheduled between November 7th and 10th, 2012 after a potential five weeks using the application. Due to scheduling conflicts, two participants had the final meeting on November 1st after only four weeks. At the final meeting, participants filled out a post-study questionnaire. There was a short exit interview. Data was collected from the phone logs a second time. We also conducted a vocabulary test to determine what vocabulary participants had learned. A description of this test is provided in Section 6.4.3.

6.4 Data Collection

Over the course of the study, quantitative and qualitative data were collected. The sources of data were questionnaires, application logging, tests of language ability, lightweight experience sampling, and interviews.

6.4.1 Questionnaires

Two questionnaires were administered: one at the beginning of the study and one at the end. The pre-study questionnaire asked for basic demographic information similar to the information collected in the formative interview study described in Chapter 4. It asked participants to rate their comfort levels for signing to Deaf adults, their child, and other parents, as well as their ability to recognize signs from those sources. Participants were also asked to report how frequently they signed with their child and what other communication methods they used. The full pre-study questionnaire is included in Appendix F.

The post-study questionnaire again asked participants to rate their comfort levels for signing and recognizing signs from Deaf adults, their children and other parents of deaf children, as in the pre-study questionnaire. It also asked questions related to the usability of SMARTSign. These questions were based on the System Usability Scale (SUS). The SUS was developed by John Brook [14]. SUS has been shown to yield more consistent ratings even at relatively small sample sizes in comparison with

Table 7: Raw participant pre-test performance

Participant	Already Knew	Did Not Know	Total Words Seen
Mr. Orange	27	80	107
Mrs. Gray	63	80	143
Mrs. Green	118	80	198
Mrs. Black	92	80	172
Mrs. Tiedye	83	80	163
Mr. White	49	80	129
Mrs. Ivory	58	80	138
Mr. Brown	25	80	105
Mrs. Yellow	12	80	92
Mr. Purple	7	80	87

other similar self-reported metrics of usability [113]. The post-study questionnaire is included in Appendix G.

6.4.2 Application Logging

Interactions with the application were recorded in a log file stored on the mobile phone. The amount of time using the application was determined by timestamps recorded when opening and closing the application or changing focus from the activity. The log file also maintained a record of the times when the participant was reminded to study. The log saved information about which components of the application were used and when, and which vocabulary terms were accessed. Figure 34 shows a sample log file which records access to components. The "component" field is the current component being used. The "action" field shows the current action taken in that component. The "detail" field shows the particular information for that instance of the action including what is being searched, what word is being studied, or what settings have changed. Figure 35 shows the log records related to specific signs. To protect the privacy of the participants, the log data was not transmitted over the Internet. Data from the logs could only be retrieved by physically plugging the phone into a computer. The data logs were collected at the end of two weeks and at the end of the study.

_id	component	action	detail	at_time
1	Home	to Study		1339948064000
2	Study	new word	vacuum	1339948065000
3	Study	study quiz		1339948065000
4	Quiz	video playing	vacuum	1339948065000
5	Quiz	choices shown	vacuum:clock:toothbrush:pen (writing tool)	1339948069000
6	Quiz	response	pen (writing tool)[vacuum]	1339948072000
7	Quiz	choices shown	vacuum:clock:toothbrush:pen (writing tool)	1339948076000
8	Quiz	response	vacuum[vacuum]	1339948078000
9	Quiz	to Study		1339948082000
10	Study	to Study		1339948112000
11	Study	review	open a jar	1339948112000
12	Study	study record		1339948112000
13	Recorder	Started	open a jar	1339948112000
14	Recorder	video recorded	open a jar	1339948126000
15	Recorder	playing recording	open a jar	1339948126000
16	Recorder	playing source	open a jar	1339948151000
17	Recorder	saved	open a jar	1339948156000
18	Recorder	to Study		1339948157000
19	Home	to Search		1340633319000
20	Search	autosuggest	happ	1340633321000
21	Search	clicked suggested	465	1340633325000
22	Search	playing	happy	1340633325000
23	Search	to Home		1340633329000
24	Note	Save text	Did something happen that caused you to use the system right now? Describe.XXXHad a free moment to study	1341158081000
25	Notification	displayed		1341583200000
26	Home	to Study		1341586536000
27	Watcher	Started		1342126092000
28	Watcher	video played	policemen.mp4	1342126095000
29	Watcher	to Home		1342126112000
30	Home	to Progress		1342127112000
31	Progress	view overview	Categories:	1342127162000
32	Progress	view detail	Connectors	1342127166000
33	Home	to Settings		1345575116000
34	Settings	changed categories	Action WordsXXXAnimalsXXXBody	1345575117000
35	Settings	changed source	Books	1345660612000
36	Settings	reminders off		1351657523000
37	Settings	reminders on		1348589455000
38	Settings	changed reminder	MondayXXXWednesdayXXXFridayXXX	1348589495000
39	Settings	changed reminder	11:00 AM	1348669694000

Figure 34: Sample log data

word	correct	seen	latest_ state	first_seen	last_seen	signed	response
not	6	7	+	1349663695000	1351568609000	1350008943000	did not like
most	2	2	+	1350008755000	1351052279000	1352430829000	
brother	2	2	+	1350268608000	1350871754000	0	work
possum	2	2	+	1349875775000	1351224029000	0	couch
zoo	3	3	+	1349727721000	1350009332000	0	too

Figure 35: Sample vocabulary data

6.4.3 Tests of Language Ability

At the beginning of the study, participants were tested on their vocabulary knowledge. In order to determine the unique set of 80 signs each participant would learn, participants were asked to watch a series of ASL videos on their phone and respond with the English equivalent. Participants responded by typing in the correct answer. As they typed, words from the dictionary were suggested to them. The suggestions were provided to help participants enter the correct form of the word, tense and spelling. If a participant knew a particular sign, that sign would not be included in the 80-word study list. Participants watched and responded to videos until 80 unknown signs were found. In this manner, each participant had a designated set of new signs to learn. A summary of participants' raw performance on the pre-test is shown in Table 7. The fewest words a participant already knew was 7, the most a participant knew was 118 ($M = 53, SD = 37$). Appendix **??** shows the complete list of all words shown during the pre-test to each participant and participant performance. All ten participants studied nine of the same words: BESIDE, BUT/HOWEVER, CHAPTER, EVERYBODY, HEN, HIDE, HIS/HERS/ITS, MONSTER, and YELL/SHOUT. They all already knew two words: BABY and CAR. Table 8 shows the similarity between all of the study lists using the Jaccard index calculation [74]. The Jaccard index is a statistic used to compare the similarity of two sets of data. A Jaccard index of 1.00 means the two study lists are identical. A Jaccard index of 0.00 means the two study lists share no common items.

Table 8: Jaccard indices for the participants' study lists

	Mr. Orange	**Mrs. Gray**	**Mrs. Green**	**Mrs. Black**	**Mrs. Tiedye**	**Mr. White**	**Mrs. Ivory**	**Mr. Brown**	**Mrs. Yellow**	**Mr. Purple**
Mr. Orange	1.00	0.45	0.26	0.29	0.36	0.54	0.51	0.76	0.65	0.57
Mrs. Gray	0.45	1.00	0.34	0.50	0.45	0.48	0.55	0.40	0.39	0.31
Mrs. Green	0.26	0.34	1.00	0.47	0.42	0.34	0.38	0.27	0.24	0.22
Mrs. Black	0.29	0.50	0.47	1.00	0.48	0.34	0.45	0.29	0.27	0.24
Mrs. Tiedye	0.36	0.45	0.42	0.48	1.00	0.48	0.47	0.30	0.31	0.29
Mr. White	0.54	0.48	0.34	0.34	0.48	1.00	0.57	0.54	0.47	0.45
Mrs. Ivory	0.51	0.55	0.38	0.45	0.47	0.57	1.00	0.48	0.45	0.42
Mr. Brown	0.76	0.40	0.27	0.29	0.30	0.54	0.48	1.00	0.63	0.60
Mrs. Yellow	0.65	0.39	0.24	0.27	0.31	0.47	0.45	0.63	1.00	0.76
Mr. Purple	0.57	0.31	0.22	0.24	0.29	0.45	0.42	0.60	0.76	1.00

At the end of the study, participants were given a test of their vocabulary knowledge. For this post-test, the list of 80 signs was separated into two groups to test both the participants' recognition and production skills. For half of the signs, participants were asked to watch the video and type in the English equivalent, the recognition test. The recognition post-test was similar to the pre-test, however there was no auto-suggest because the tests were manually graded. For the other half of the signs, participants were given the English word and were asked to produce the ASL sign, the production test. This testing method allowed us to evaluate both the productive and receptive skills of the participants. For the production portion of the post-test, participants' signs were recorded and scored by two individuals who know ASL. Each sign was initially given a score out of seven points. Correct handshape, motion, and location were worth two points each, and correct orientation was worth one point. An interrater reliability analysis using the Kappa statistic was performed to determine consistency among raters. The interrater reliability for the raters was found to be Kappa = 0.625 ($p < 0.001$), 95% CI (0.570, 0.680). This agreement is considered substantial [64]. However, the 95% confidence interval includes values that indicate only moderate agreement. To improve interrater reliability and to allow better comparison with Henderson-Summet's rating scheme [43], we also categorized produced signs as either correct, partially correct, or incorrect. The interrater reliability for the raters was found to be Kappa = 0.719 ($p < 0.001$), 95% CI (0.664, 0.774), indicating substantial agreement. All further references to production scores in this chapter use the correct, partially correct, and incorrect scores.

6.4.4 Lightweight Experience Sampling

Experience sampling is the practice of asking participants to make notes of what they are experiencing in real time. The primary focus of the study was testing whether SMARTSign could improve vocabulary learning. However, we also wanted to discover

some of the participants' context when using the application. Studying where and why participants choose to access the application could help improve the design of the application. These answers can provide some measure of how participants incorporate the study sessions into their everyday lives. To this end I designed a lightweight experience sampling mechanism into the application in the NOTE component. Participants could access it at any time by selecting the Note button on the main screen of the SMARTSign application. Participants could create a note either by typing or by recording a voice note. In the NOTE component, participants received the prompt "What would you like to share about the application?" The NOTE component also automatically activated upon opening SMARTSign every three days with one of three prompts. These three prompts are:

1. Where are you right now?

2. Did something happen that caused you to use the system right now? Describe.

3. Are you using the system with anyone else right now? Describe.

Each of these prompts was created to help understand the context and reasons for accessing SMARTSign. While location can be determined through logging the GPS location of the device, we felt that recording that information incurred too high of a privacy cost for the benefit we might receive from recording it. Instead, by leaving the questions open, we allowed participants the freedom to be as detailed or as vague as they wanted to be, and we were still able to collect some meaningful information. By asking a question every three days, we had the potential to ask every question three times over the course of four weeks.

6.4.5 Interview

Participants were interviewed at the final meeting. In the interview, participants were asked to describe any strategy they had for using the application to study. They were

asked about the role of notifications in their decision to study. If notifications played no role, participants were asked what prompted them to study. To understand the reasons behind their decision to record or not record themselves with the application, participants were asked how they felt about seeing themselves in the camera and recordings. The participants were asked how the limitations of the dictionary included in SMARTSign impacted their use and view of the SEARCH component. SMARTSign has a relatively small dictionary with matches for only 1,183 English words. This limitation meant participants were likely to encounter words not in the dictionary when using the SEARCH component. Participants were asked if they were doing anything outside of using SMARTSign to learn ASL. Participants in the *Stories* condition were asked how they felt about organizing vocabulary around signing the stories, and if they had signed any of the stories to their child over the course of the study. Participants in households with two participants in the study were asked how that impacted their use of the application.

6.5 Results

In this section I analyze the results gathered from the data described in the previous section. The results are based on multiple data sources, therefore the results are organized by theme: usability, ASL comfort and frequency, system use, learning, locations SMARTSign was used, notifications, collaboration, and using *Story* vocabulary.

6.5.1 Usability

Figure 36 shows the SUS scores of nine participants. Participant Tiedye did not complete the full survey. In the figure, the dashed line indicates the mean and the dotted lines indicate one standard deviation above and below the mean. The mean SUS score across all nine participants was 82.2 with a standard deviation of 20.2, which indicates that the current version of SMARTSign is acceptable with a user friendliness rating of good to excellent. [9].

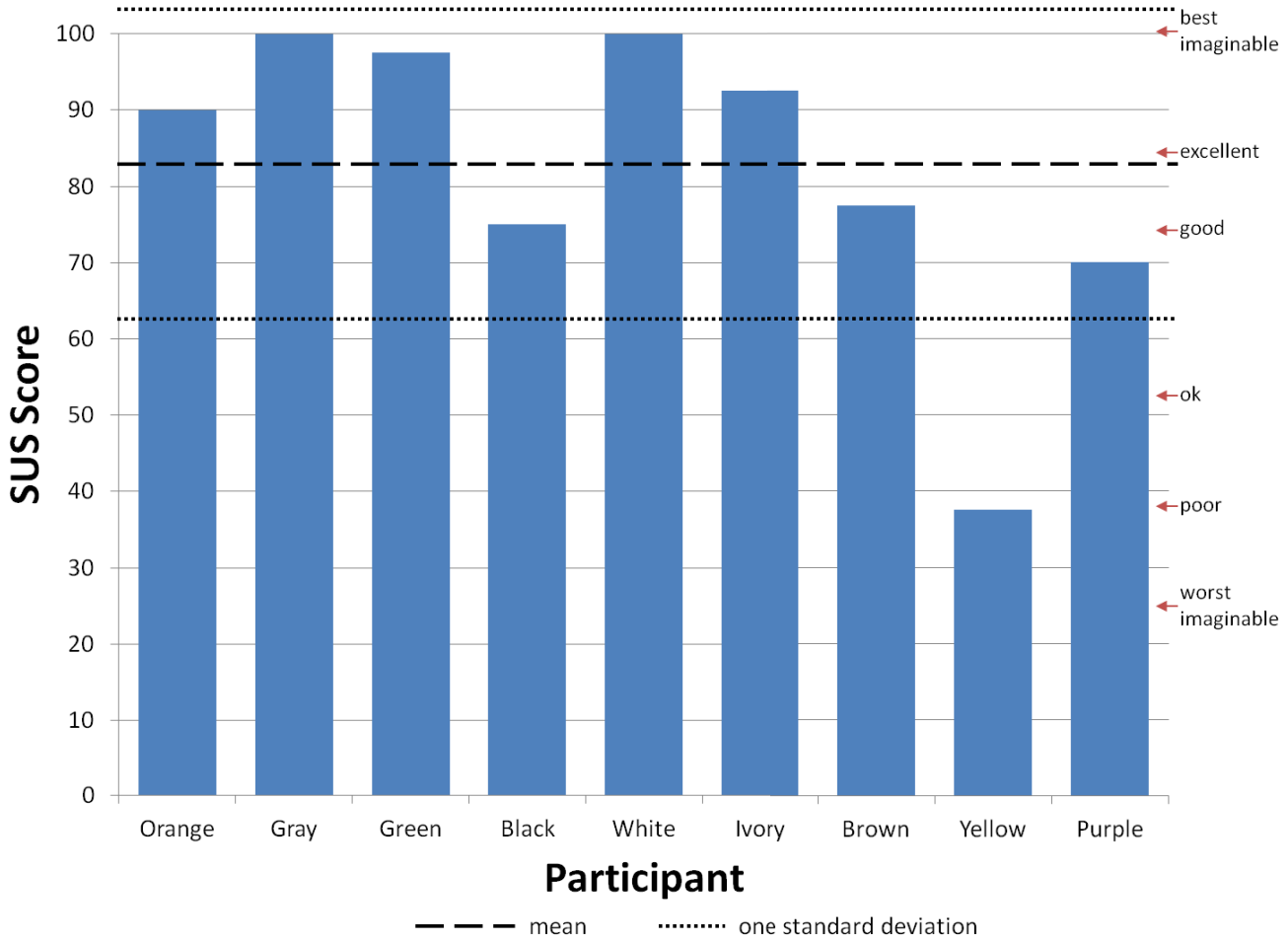


Figure 36: SUS Scores by participant.

The notes, free response section of the post-study questionnaire, and interview lend insight into the usability problems of SMARTSign. There were five main areas that were reported as sources of usability problems: recording, source videos, content, the phone, and design. A summary of all usability issues is shown in Table 9.

Table 9: Summary of SMARTSign usability issues

Issue	**Mr. Orange**	**Mrs. Gray**	**Mrs. Green**	**Mrs. Black**	**Mrs. Tiedye**	**Mr. White**	**Mrs. Ivory**	**Mr. Brown**	**Mrs. Yellow**	**Mr. Purple**	**Total**
RECORDING											9
bad angle	X	X		X	X		X	X		X	7
inappropriate location			X	X							2
not confident with sign									X		1
SOURCE VIDEOS											4
need more detail			X						X	X	3
people in the videos								X			1
CONTENT											4
missing signs in search				X				X			2
questionable ASL					X	X					1
ambiguity of meaning						X					1
PHONE											3
battery life								X			1
do not like Android										X	1
bad camera							X	X			1
DESIGN											2
distracted during quiz								X	X		2
want to choose topic								X			1

The RECORDER component was the greatest source of usability issues. Nine participants reported having problems using the RECORDER. The most common problem was finding a good angle to place the phone to record without the phone falling. Participants found it hard to create good videos. This was not a problem in pilot studies of the application, so we made the decision not to give participants a stand for the phone because it would add more for them to carry and keep track of. In future deployments, a stand should be provided. Another common problem with the RECORDER was the application asking them to record at inappropriate times, whether in public, or at night when they had already changed for bed. This problem could be alleviated in the future if the application asks at the beginning of each session if learners are in a situation where they are able or willing to sign. One participant explained that she did not use the RECORDER component because she never felt she was comfortable enough with a how to perform sign.

The next largest source of usability issues reported were the source videos and content. Four participants reported having problems in each of these areas. Source video issues were problems with the way the signs are presented in the videos. Three participants felt that they were unable to recreate the signs from the videos easily and suggested adding options to be able to play the video in slow motion or zoom into specific aspects of the sign such as the handshape. These comments on the source video reflect an instance where results from the study in Chapter 3 (with individuals unmotivated to learn ASL) were misleading. In the previous study, there was no real penalty for signing incorrectly, so participants just signed something and were most often correct. In the SMARTSign study, the participants want to learn the sign, so the speed at which the sign is shown in the source video may cause them to be less confident about knowing the sign. In future versions of SMARTSign, including slower or zoomed in videos in addition to the source video could help ease this transition. These additional videos should not replace a normal speed video because slow videos

will not help learners get used to the speed of natural ASL. One participant mentioned that he had problems recognizing the signs of a specific signer in the source videos who had skinny fingers. This participant also mentioned that he learned more from the older signers than from the younger signers. He did have positive things to say about the variety of signers in the application. This participant also enjoyed learning from the signers who looked like they were having fun as opposed to those who looked serious. Feedback from this participant will be important to consider as we update the videos in our database.

The content issues reported dealt with missing signs and the reliability of the existing signs. While a number of participants using the SEARCH component came across words that were not in the dictionary, only two participants found it to be a problem. One participant said there were not enough words in the dictionary, and another participant listed the words she searched for that were not there. Two participants, both in the same household, talked about some of the signs being "questionable." The signs they questioned are not typically used when signing ASL but correlate with English words. The sign for "and" is an example of one of the signs they questioned. The decision to include these English-based signs in the dictionary was partially due to the transliteration of stories written in English into ASL and partially due to having a target audience of hearing parents. Leaving English-based signs out completely might have confused learners not very familiar with ASL, but keeping them in confused participants who were more familiar with ASL. One participant had an issue with the ambiguity of the signs in the dictionary. He said that in the pre-study vocabulary test he answered with one meaning of a sign, but it was marked wrong because that video was associated with another sign in the database. While I attempted to eliminate all duplicate videos from the database, two remained in the version of SMARTSign deployed for this study. These duplicate videos were the signs ROOM/BOX and FOOD/EAT. Having multiple videos in the database with the

same meaning, meant that not all participants were able to study 80 completely new words. This discrepancy between pre-test knowledge and the post-test was accounted for in the results.

The phone itself was the source of some usability problems. Three participants discussed usability issues with the phone. One participant felt that the battery drained too quickly. Another participant did not like the Android OS and prefers the iPhone. A third participant felt that the camera was too sensitive to light resulting in poor quality recordings.

Two participants had issues with the design of the application. They wanted the ability to replay the video during the quiz if they were distracted and missed it the first time instead of being forced to show an answer. For these participants the penalty of getting a sign they had not actually seen wrong was too high. A replay function in the quiz is a reasonable addition for future versions of the application. One of these participants also wished he could choose a specific theme to study as in other smartphone ASL applications, for example, learning all of the food signs. This feature was in the application, but might not have been discovered by the participant. The benefits of the feature would not have been very high in the *Word Types* condition because the participants were studying so few words in each category.

6.5.2 ASL Comfort and Frequency

Participants were asked about their level of comfort signing to and recognizing the signs of three communication partners: Deaf adults, their child, and other parents of deaf children in the pre- and post-study questionnaires. Figure 37 shows a graph of the responses both before and after the study. Error bars indicate the standard error of the mean. A paired-samples t-test was conducted to evaluate the impact of using SMARTSign for each of these measures. A statistically significant increase in participants' comfort levels producing and recognizing signs was found with all three

communication partners. The result of these t-tests are shown in Table 10.

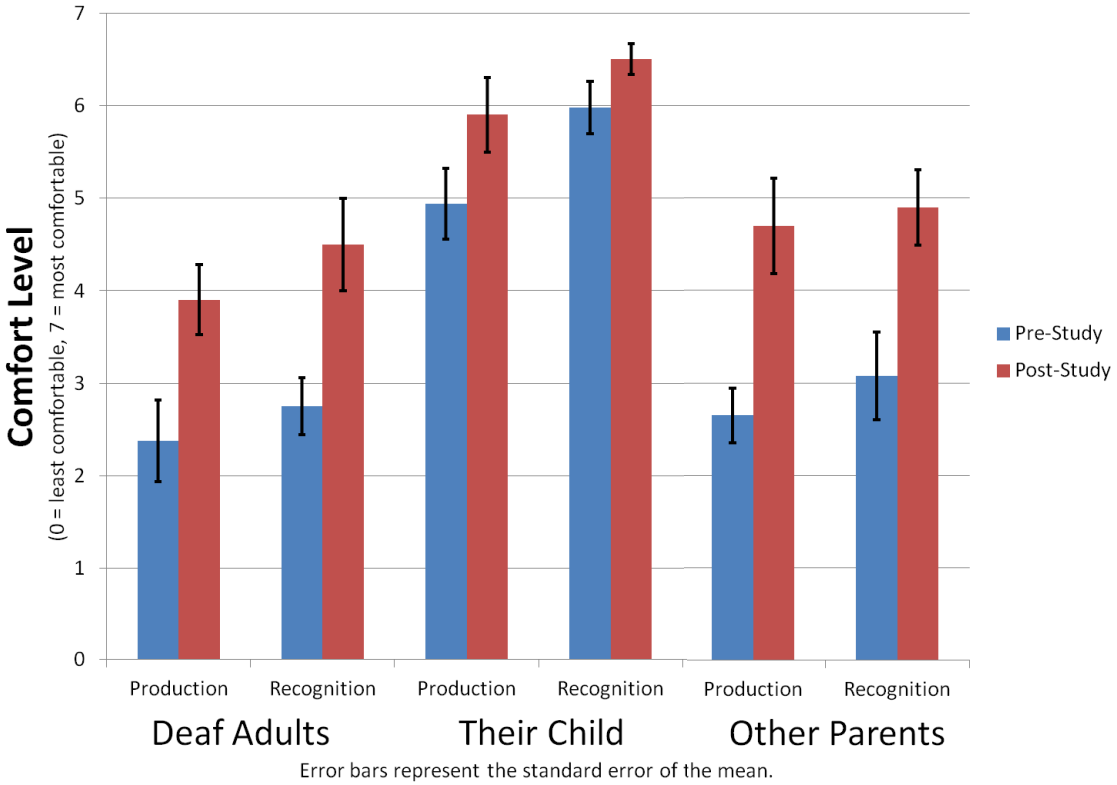


Figure 37: Level of comfort before and after the study

Table 10: Paired-samples t-test results of signing comfort

Partner	**Type**	**Pre-Study**		**Post-Study**		**Paired-t results**				
		M	**SD**	**M**	**SD**	**t**	**df**	**p**	**eta squared**	**effect size**
Deaf adult	Production	2.38	1.39	3.9	1.20	-2.98	9	0.02	0.50	large effect
	Recognition	2.75	0.97	4.5	1.58	-2.83	9	0.02	0.47	large effect
Their child	Production	4.94	1.22	5.9	1.29	-2.26	9	0.05	0.36	large effect
	Recognition	5.98	0.89	6.5	0.53	-2.91	9	0.02	0.48	large effect
Other parents	Production	2.65	0.93	4.7	1.64	-3.18	9	0.01	0.53	large effect
	Recognition	3.08	1.50	4.9	1.29	-3.54	9	0.01	0.58	large effect

A paired-samples t-test was also conducted to evaluate the impact of the intervention on the frequency with which participants sign with their child and with others. Figure 38 shows the reported frequencies before and after the intervention. There was no statistically significant change in the frequency of signing with their child from before the study ($M = 4.72, SD = 1.68$) to after the study ($M = 5.3, SD = 0.82$), $t(9) = -1.45$, $p = 0.18$ (two-tailed). A statistically significant increase in the frequency of signing with people other than their child did increase from before the study ($M = 2.73, SD = 0.82$) to after the study ($M = 3.67, SD = 0.71$), $t(9) = -2.5$, $p = 0.04$ (two-tailed). The eta squared statistic (0.44) indicated a large effect size.

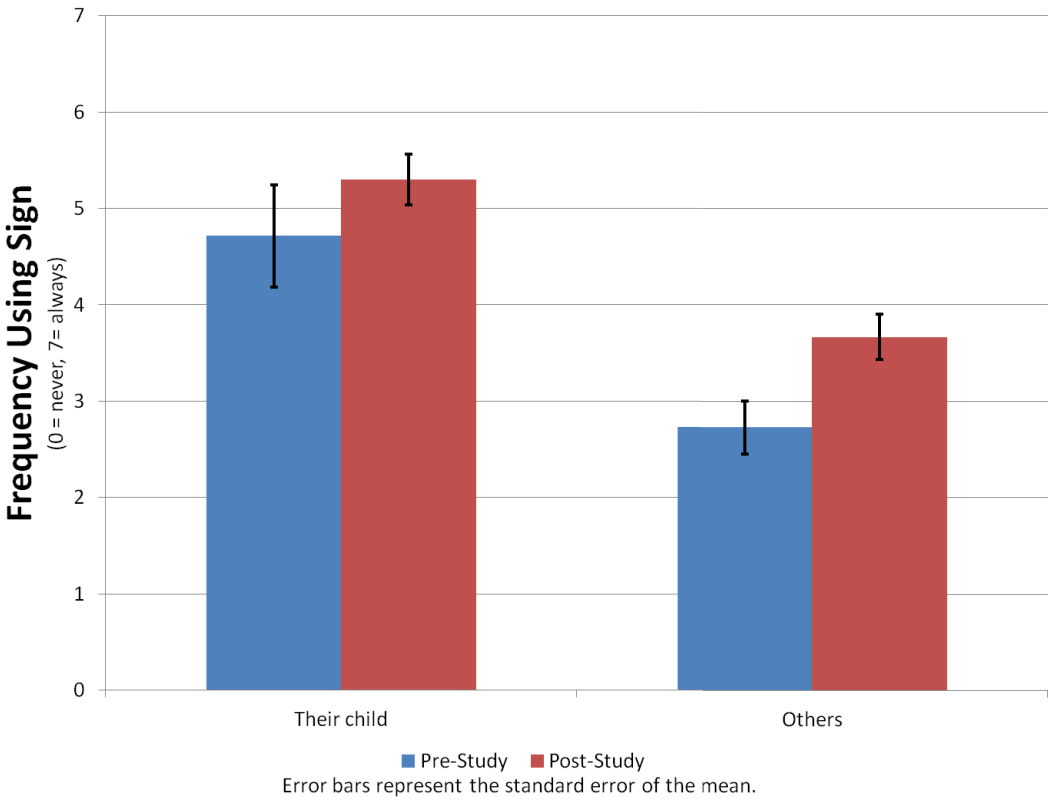


Figure 38: Frequency participants sign with their child and others

A mixed between-within subjects analysis of variance was conducted to assess the impact of the study condition on participants' comfort levels for using and recognizing ASL. For all but one measure, no significant differences were found. For the measure

Table 11: Level of comfort recognizing a Deaf adult's signs pre- and post-study for both study conditions

	Word Types			***Stories***		
Time period	**N**	**M**	**SD**	**N**	**M**	**SD**
Pre-study	5	2.75	0.87	5	2.75	1.17
Post-study	5	3.40	1.14	5	5.60	1.14

of comfort recognizing the signs of Deaf adults, there was no significant interaction between condition and time, Wilks Lambda = 0.65, $F(1, 8) = 4.32$, $p = 0.07$, partial eta squared = 0.35. There was a substantial main effect for time, Wilks Lambda = 0.42, $F(1, 8) = 10.94$, $p = 0.01$, partial eta squared = 0.58, with both groups showing an increase in comfort levels recognizing Deaf adults' signs over time. The main effect comparing the two conditions was significant, $F(1, 8) = 6.29$, $p = 0.04$, partial eta squared = 0.44, suggesting that the *Stories* condition was more effective at helping participants increase their comfort levels for recognizing signs over the *Word Types* condition. Table 11 shows the means and standard deviations for the two conditions.

6.5.3 System Use

The application logs generated data on the amount of time spent performing different tasks within SMARTSign. The four main components: Study, Recorder, Search, and Watch were accessed a total of 3,078 times. For the purposes of this analysis the Study component will be referred to as Quiz when referring to the multiple choice quiz only, and Recorder when the Recorder component was activated. Table 12 shows the access frequencies for each of the four components. There were 2,923 activities associated with the Study component. Table 13 shows the frequencies for studying a new or review word.

A paired-samples t-test was conducted to evaluate the difference between studying a new word versus studying a review word using the quiz. There was a statistically significant decrease in the number of attempts needed when studying a new word

Table 12: Table of component access frequencies

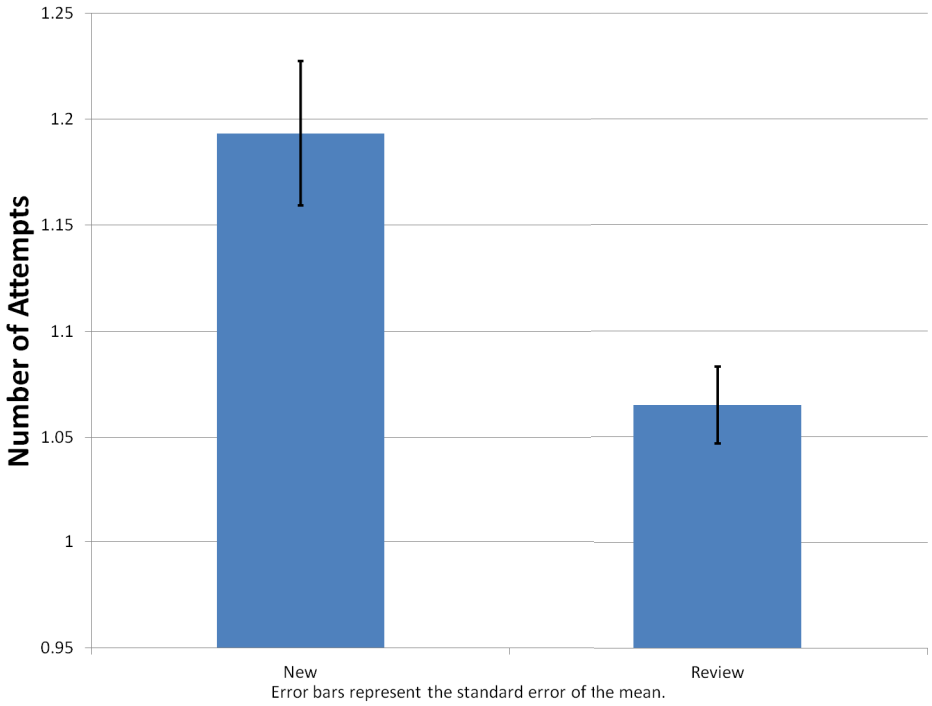
Component	Frequency	Percent
Quiz	1861	60.5
Recorder	1062	34.5
Search	117	3.8
Watch	38	1.2

Table 13: Table of study type frequencies

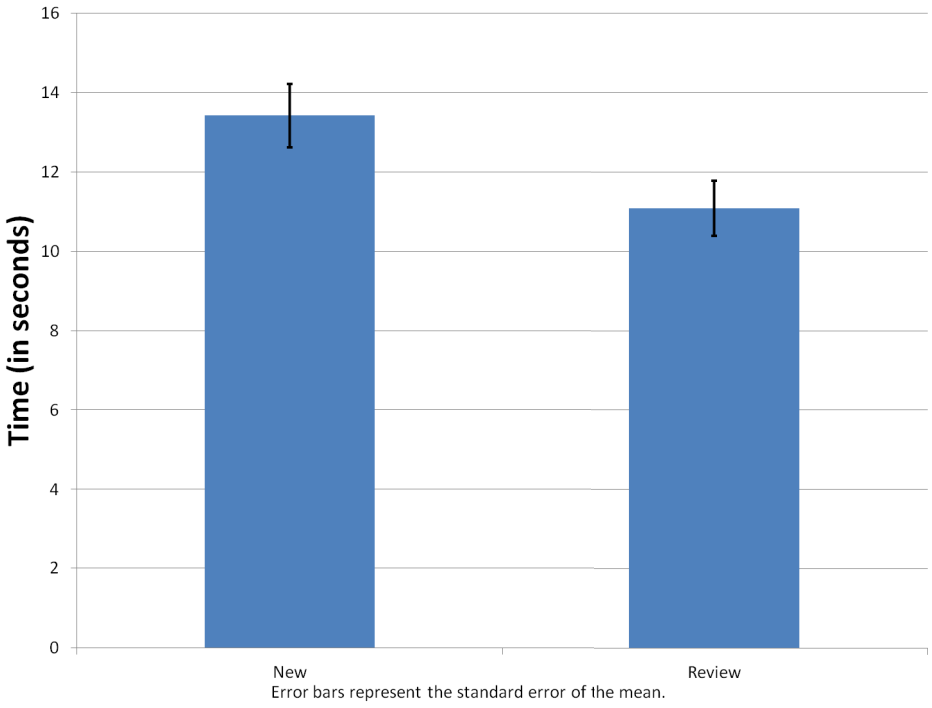
Type	Frequency	Percent
New	761	26
Review	2162	74

($M = 1.19, SD = 0.11$) versus studying a review word ($M = 1.06, SD = 0.08$), $t(9) = 5.39$, $p < 0.001$ (two-tailed). Figure 39(a) shows the average number of attempts needed for new and review words. A statistically significant decrease was also found in the time it took to complete a QUIZ involving a new word ($M = 13.4$ seconds, $SD = 2.53$ seconds) or a review word ($M = 11.08$ seconds, $SD = 2.20$ seconds), $t(9) = 3.23$, $p = 0.01$ (two-tailed). Figure 39(b) shows the average amount of time needed for new and review words. The relationship between the number of attempts to answer a quiz and the time it took to answer was investigated using Pearson product-moment correlation coefficient. Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity, and homoscedasticity. There was a strong, positive correlation between the two variables $r = 0.63$, $n = 1851$, $p < 0.001$, with a low number of attempts associated with lower times. The strong correlation between attempts and response time indicates that the number of attempts it takes to answer the *Quiz* explains 39.7 percent of the variance associated with the response time.

Figure 40 shows the average task completion time for males and females performing specific study activities: answering a new word QUIZ, answering a review word QUIZ, using the RECORDER, and SEARCH. An independent-samples t-test was



(a) Attempts to answer



(b) Time to answer

Figure 39: Comparing studying new and review words in the Quiz

conducted to compare the completion time for males and females. No significant differences were found for review word quizzes, recordings, or search. Males ($M = 15.5$ seconds, $SD = 2.0$ seconds) took a significantly longer time to respond to the quiz for a new word than females ($M = 12.0$ seconds, $SD = 1.7$ seconds), $t(8) = 2.27$, $p = 0.05$ (two-tailed).

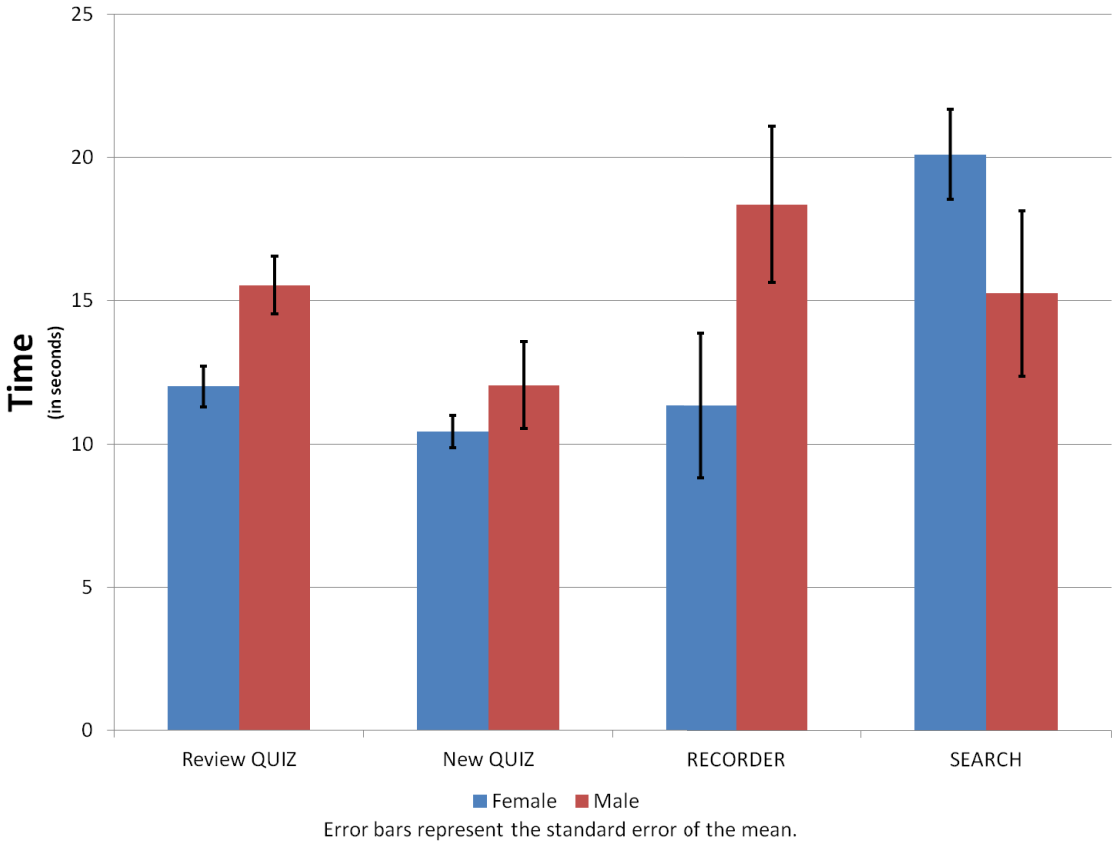
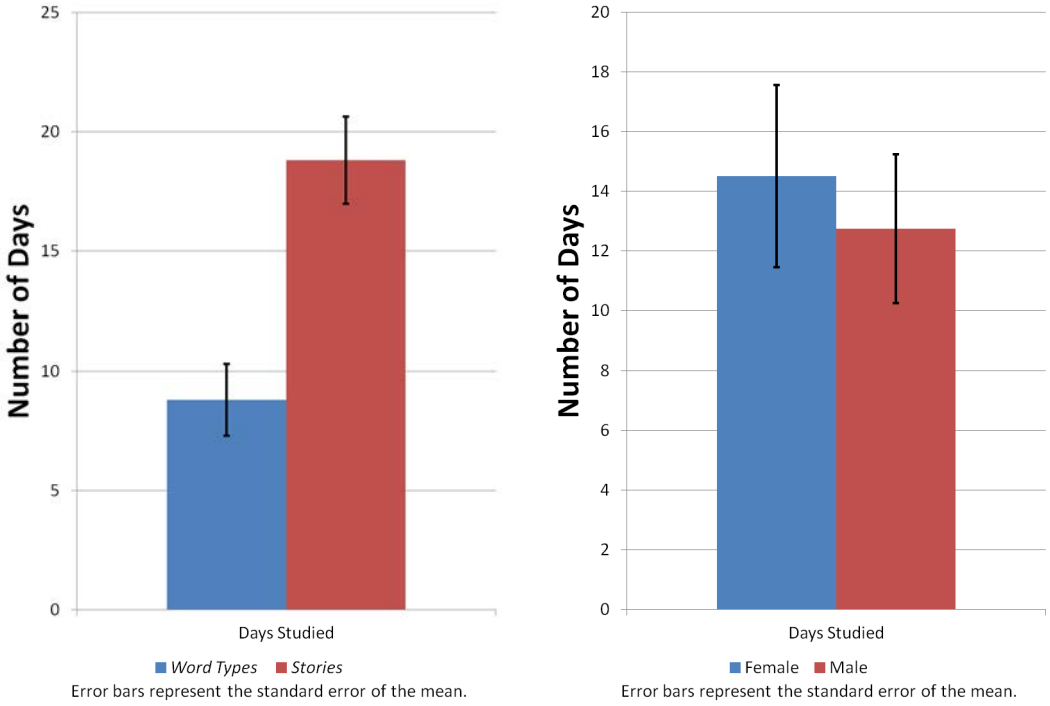


Figure 40: Average time to complete activities in SMARTSign

Participants used SMARTSign for an average of 13.8 days ($SD = 6.34$ days). The lowest number of days a participant studied was 5 days and the highest number of days a participant studied was 25 days. Figure 41 shows the average number of days SMARTSign was accessed grouped by study condition and gender. Using an independent-samples t-test, participants in the *Story* condition accessed SMARTSign a statistically significant higher number of days ($M = 18.8$ days, $SD = 4.09$ days) than participants in the *Word Types* condition ($M = 8.8$ days, $SD = 3.35$ days),

$t(8) = -4.23$, $p < 0.001$ (two-tailed). There was no significant difference between males and females.



(a) Condition (b) Gender

Figure 41: Number of study days by condition and gender

Figure 42 shows a histogram of session duration frequencies. Sessions are defined as a continuous state of interaction with the application. If the user stops interacting with the application for longer than 60 seconds, the next interaction with the application is considered the start of a new session. In the figure, the session durations are divided into one-minute bins. The distribution is skewed to the right with most of the sessions lasting less than five minutes. However, the longest learning sessions in the study lasted up to 22 minutes.

Besides the duration of a session, the session gaps, the amount of time that elapses between sessions, are also important. Figure 43(a) shows a histogram of the session gap durations. In this figure, the session gap durations are divided into 25 hour bins. The variation in session gap duration is very high. Participant session gaps could last

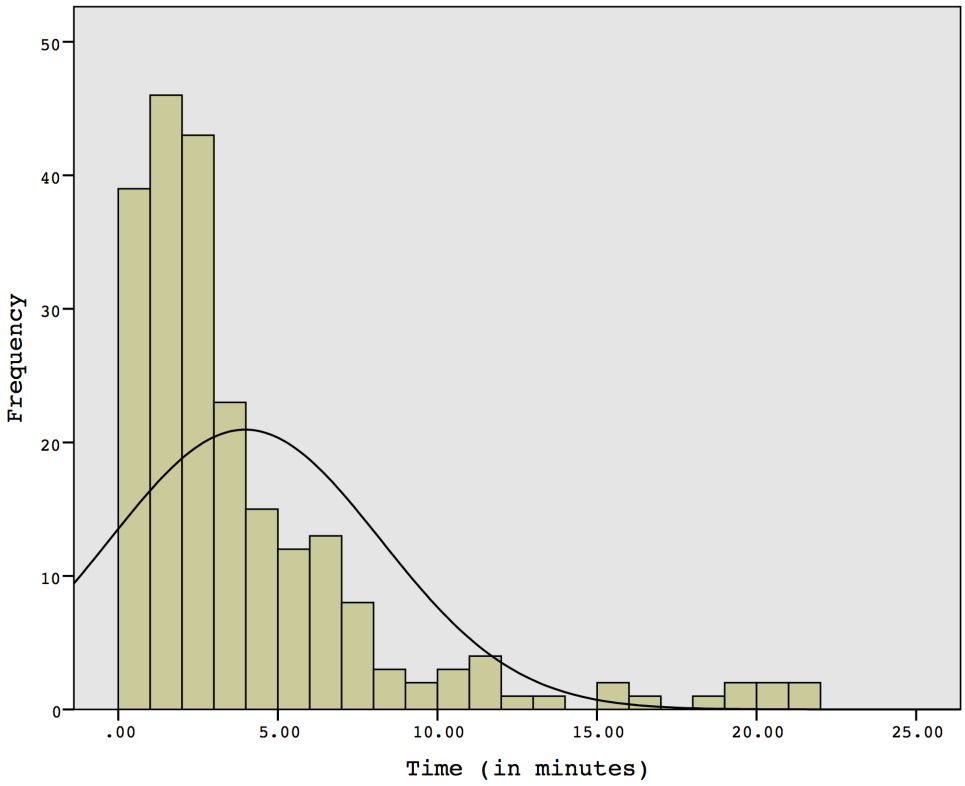
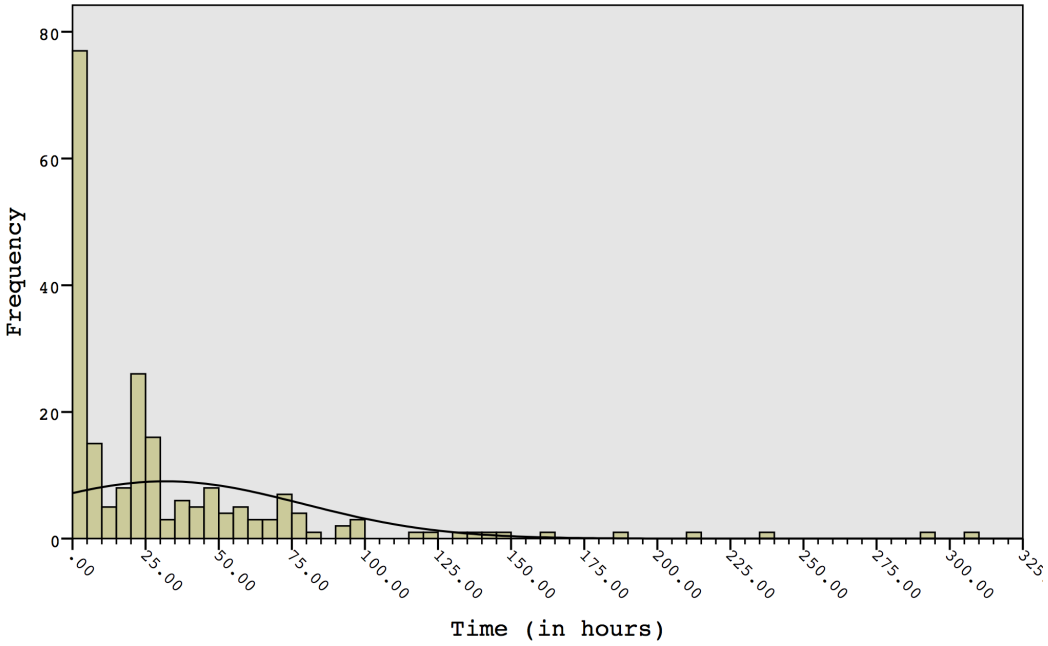


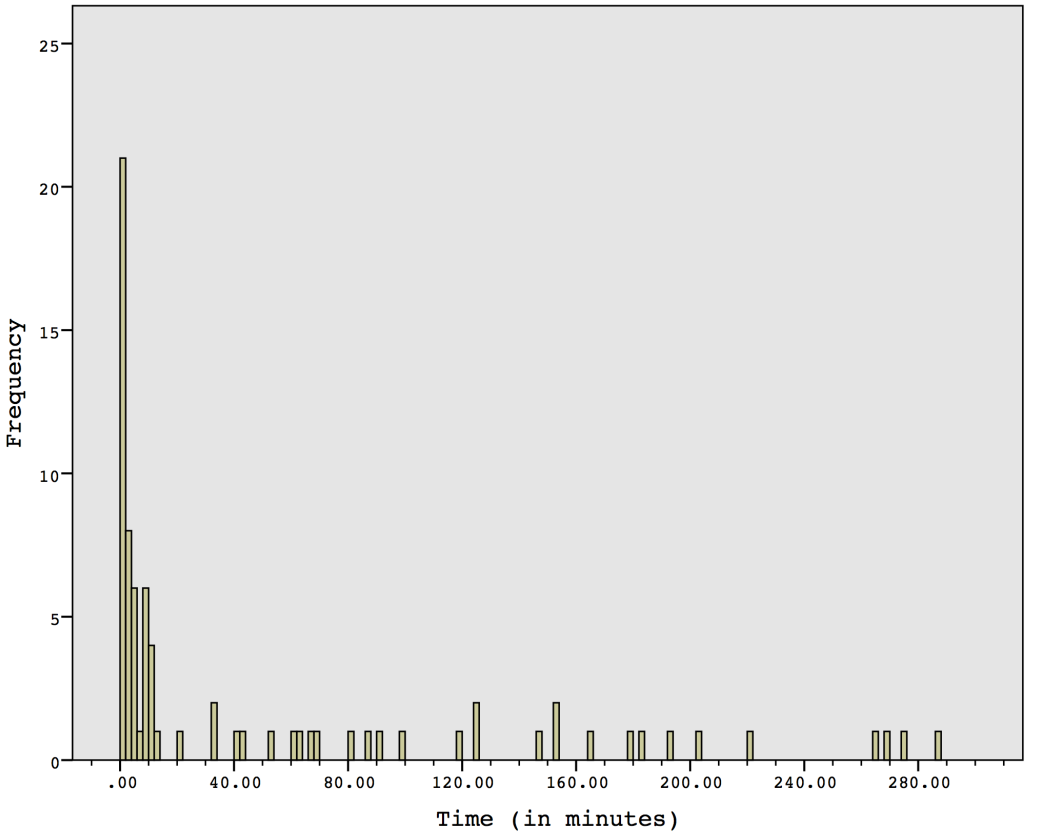
Figure 42: Histogram of session durations

up to 320 hours, which is 13 days, almost two full weeks. This high variance means that in Figure 43(a), the highest frequency of session gap durations was five hours or less. Figure 43(b) shows a histogram of session gap durations for only those session gaps less than five hours. In this figure, the session gap durations are divided into bins of 2 minutes. The histogram still shows a strong skew to the right. Session gaps of 2 minutes or less have the highest frequency. Session gaps this short would be associated with resuming a study task after interruption. Referring back to Figure 43(a), the other most frequent session gap duration is between 20 and 25 hours, indicating participants studying at the same time every day.

Figure 44 shows the total amount of time spent using SMARTSign as well as the four main components. This study time is separated by condition in Figure 44(a) and by gender in Figure 44(b). There are no significant differences due to gender on overall time using SMARTSign, or on the total time spent using any of the components. With

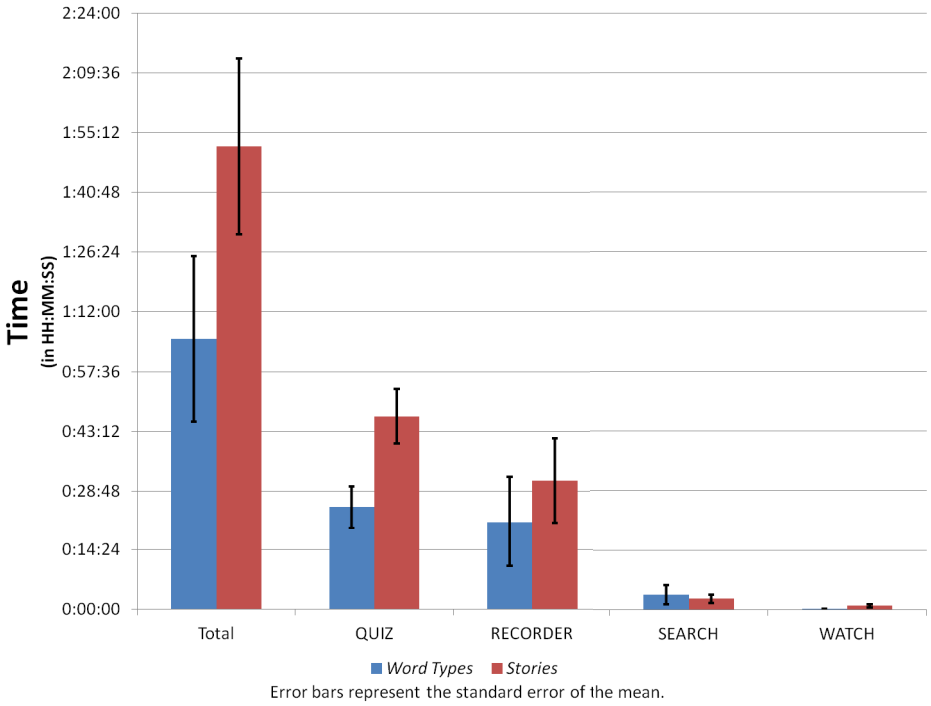


(a) Full histogram

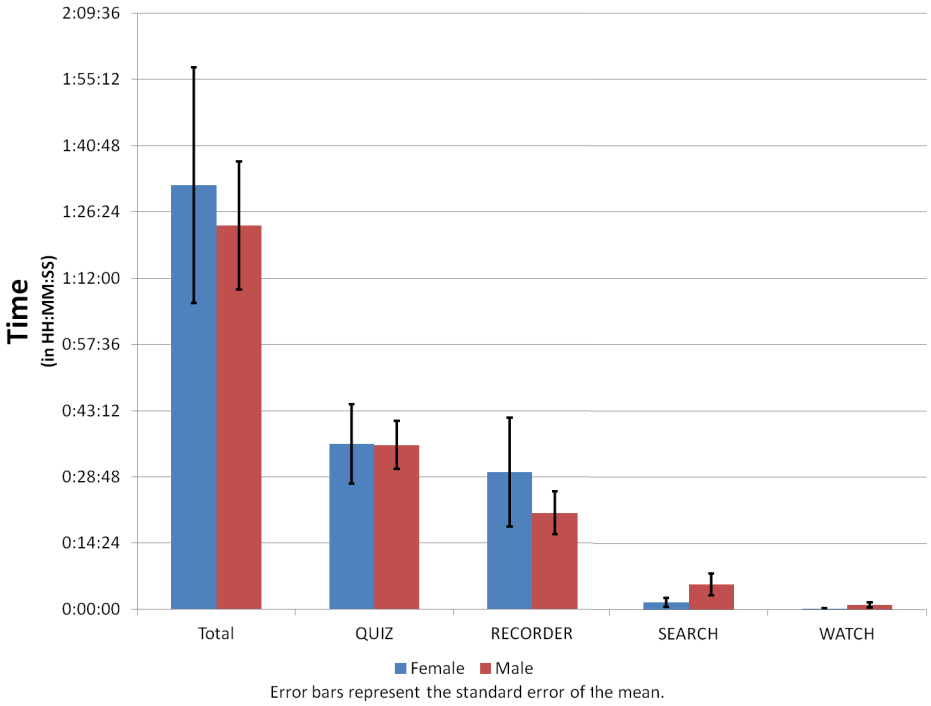


(b) Detailed histogram of gaps less than five hours

Figure 43: Histograms of session gap durations



(a) Condition



(b) Gender

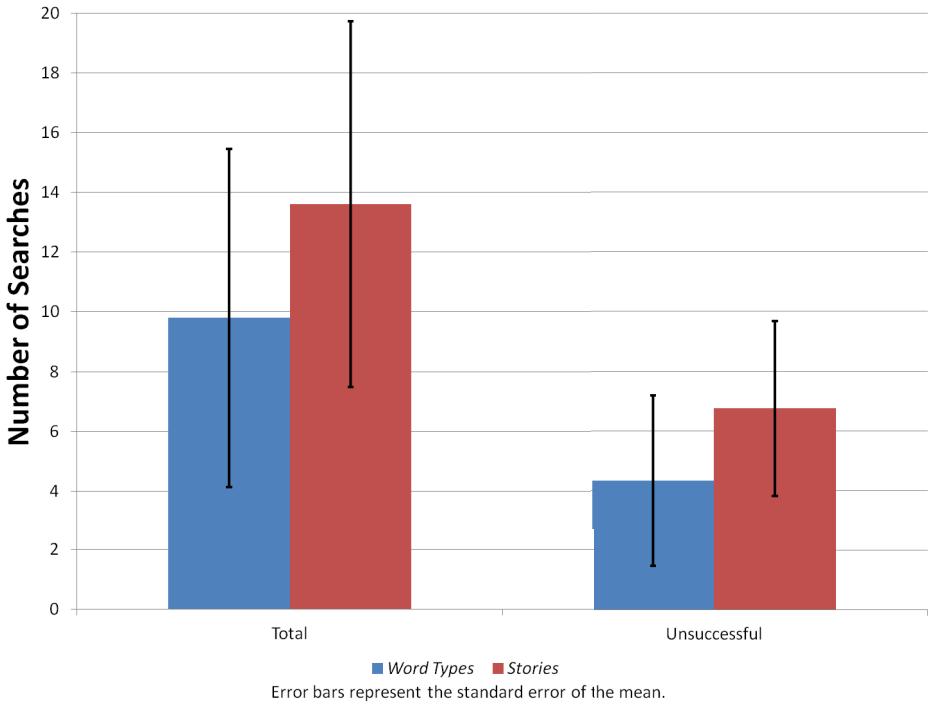
Figure 44: Total time spent studying

regards to study condition, there is a statistically significant increase in total time spent using the quiz in the *Stories* condition ($M = 46.81$ minutes, $SD = 14.66$ minutes) over using the quiz in the *Word Types* condition ($M = 24.91$ minutes, $SD = 11.10$ minutes), $t(8) = -2.66$, $p = 0.03$. Most of the time was spent either using the QUIZ or the RECORDER component. Very little time was spent using the SEARCH component or the WATCH component. Figure 45 shows SEARCH behavior divided by condition and gender. While participants in the *Stories* condition used the quiz component longer than participants in the *Word Types* condition, the trend did not extend to the other components. There are no significant differences in search behavior: neither total number of searches or number of unsuccessful searches with regards to study condition, as shown in Figure 45(a). Figure 45(b) shows the number of total searches and unsuccessful searches by gender. An independent-samples t-test showed that that males searched ($M = 21.5, SD = 13.2$) significantly more times than did females ($M = 5.2, SD = 7.3$), $t(8) = -2.55$, $p = 0.03$ (two-tailed). Use of the WATCH component was too rare for statistically significant differences between genders to arise.

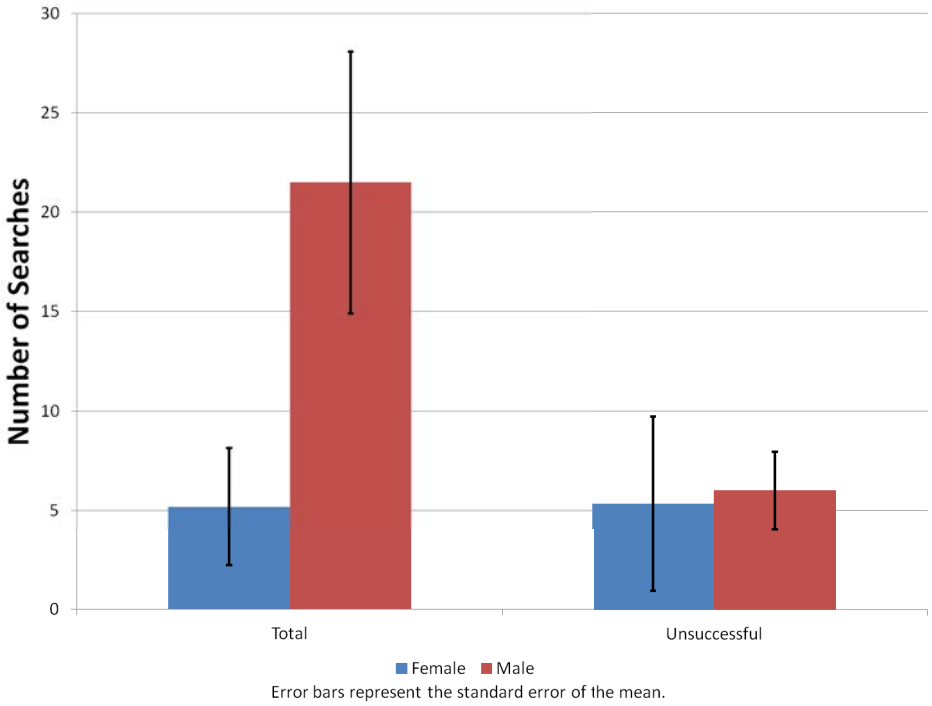
Three participants changed the application settings over the course of the study. Mr. Brown changed his notification time from 10:00 AM to 8:00 AM. Mrs. Green changed the number of words she would study per day from ten to "no limit." She studied her entire vocabulary list on the first day. Mr. White changed his signs per day from five to ten on the fourth day of the study. If he had not done so, he most likely would not have finished studying all of his words before the end of the study.

6.5.4 Learning

In this section, I look at how well SMARTSign was able to help participants learn to recognize and produce the 80 signs they studied based on the vocabulary post-test. In order to better understand these results, information about participants' prior



(a) Condition



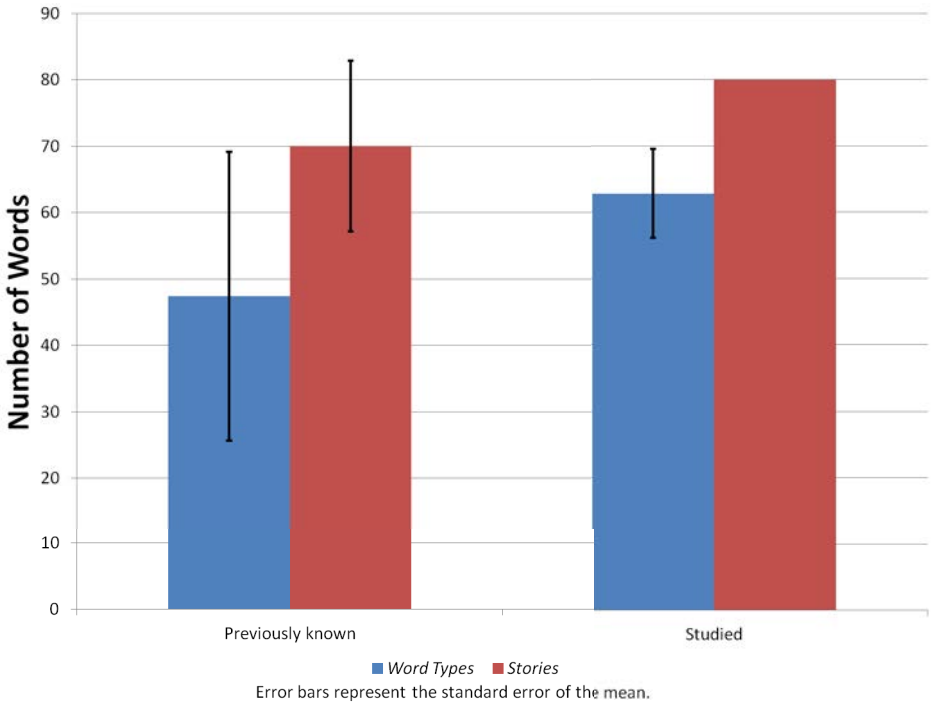
(b) Gender

Figure 45: Number of searches by condition and gender

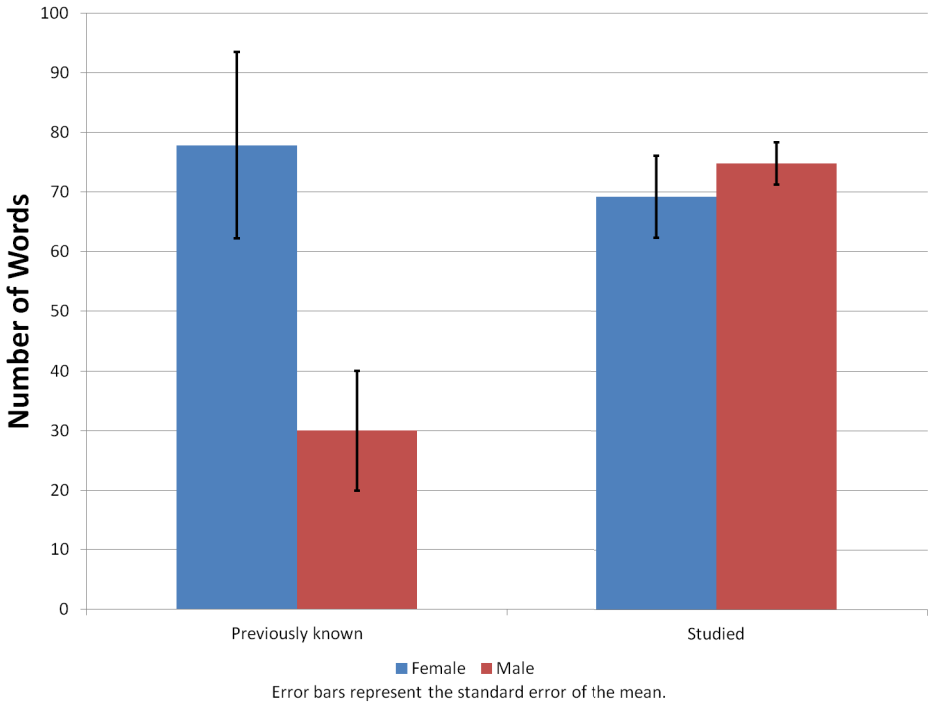
knowledge of ASL and their success in studying all of the words is needed. Figure 46 shows the number of words known before the study, as discovered by the pre-test, and the number of words seen at least once during the study, grouped by condition and gender. With regards to study condition, there was no significant difference between the number of words previously known by participants in the *Word Types* condition ($M = 47.4, SD = 48.6$) and participants in the *Stories* condition ($M = 70.0, SD = 28.8$), $t(8) = -0.894$, $p = 0.40$. There was also no significant difference between the number of words participants saw during the study for the *Word Types* condition ($M = 62.8, SD = 15.1$) and *Stories* condition ($M = 80, SD = 0$), $t(4) = -2.55$, $p = 0.06$). However, the p-value is very close to statistical significance and would have been significant if equal variances had been found. Since all participants in the *Stories* condition studied all 80 possible words, a ceiling effect caused the difference in variance of the two condition populations to be too large for traditional p-value calculations.

As was expected, based on the literature stating that mothers bear the primary communication burden with their deaf child [79], mothers ($M = 77.8, SD = 38.3$) knew significantly more signs at the beginning of the study than fathers ($M = 30.0, SD = 20.1$), $t(8) = 2.265$, $p = 0.05$. During the course of the study there was no difference in the number of words seen by females ($M = 69.2, SD = 16.9$) and males ($M = 74.8, SD = 7.1$), $t(7.164) = -0.721$, $p = 0.49$.

There were four measures of language ability: percentage of words recognized, percentage of words produced correctly, percentage of words produced partially correctly, and percentage of words produced incorrectly. These measures were all adjusted to include only the signs that were seen by the participant over the course of the study and were not answered correctly during the vocabulary pre-test. Table 14 shows how each of the participants performed on the tests of language ability.



(a) Condition



(b) Gender

Figure 46: Number of words known and studied

Table 14: Participant learning performance

			Recognition	Production		
Participant	**Pre-test Score**	**Words Seen**	**Correct %**	**Correct %**	**Partially Correct %**	**Incorrect %**
Mr. Orange	30	80	64.10	31.58	42.11	26.32
Mrs. Gray	69	80	83.33	42.11	28.95	28.95
Mrs. Green	125	80	56.76	30.56	41.67	27.78
Mrs. Black	96	80	77.78	22.50	42.50	35.00
Mrs. Tiedye	99	80	68.57	31.03	41.38	27.59
Mr. White	56	80	97.22	72.97	10.81	16.22
Mrs. Ivory	64	50	65.22	37.50	37.50	25.00
Mr. Brown	27	65	51.72	26.47	41.18	32.35
Mrs. Yellow	14	45	50.00	9.52	0.00	90.48
Mr. Purple	7	74	59.46	16.22	35.14	48.65
MIN	7	45	50.00	9.52	0.00	16.22
MAX	125	80	97.22	72.97	42.50	90.48
MEAN	58.70	71.40	67.42	32.05	32.12	35.83
STD. DEV	39.51	13.53	14.88	17.29	14.91	20.91

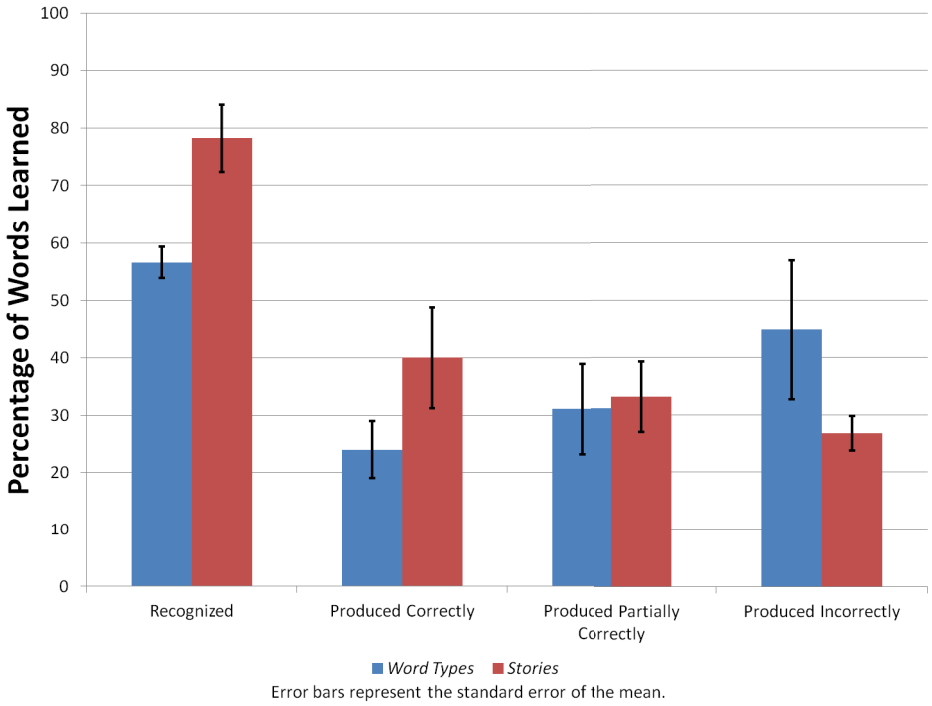
The table includes the pre-test score and the number of words actually seen during the study. The mean percentage of words correctly recognized on the post-test is 67.42% ($SD = 14.88\%$). Participants produced an average of 32.05% words correctly ($SD = 17.29$). Figure 47 shows performance on the recognition and production tests by condition and gender. Participants in the *Stories* condition ($M = 78.2\%, SD = 13.0\%$) recognized significantly more signs than participants in the *Word Types* condition ($M = 56.6\%, SD = 6.1\%$), $t(8) = -3.35$, $p = 0.01$. Significant differences were not found for production. No significant differences were found for any of the learning measureswith regards to gender.

6.5.5 Locations SMARTSign was Used

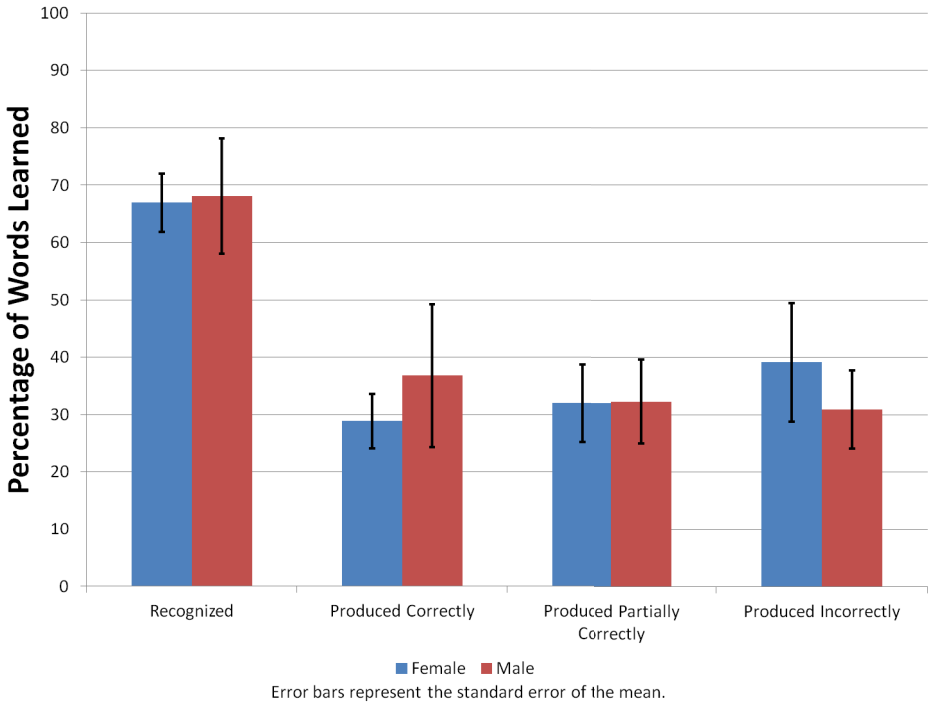
The lightweight experience sampling gave insight into where SMARTSign was used during the course of the study. Table 15 shows the locations mentioned by participants in the experience sampling and in the post-study interview. The home was the most common place participants reported using SMARTSign, with eight participants mentioning use at home. Specific locations in the home included the kitchen, on the couch, and in their child's playroom. Two participants talked about using the application at work. The car and the doctor's office are two other locations where participants reported using SMARTSign. Because participants primarily used SMARTSign once a day, it is not surprising that the primary use was in the home. Participant Black, who used the application at the doctor's office, said that the location made it difficult to use the *Recorder*.

6.5.6 Notifications

The Notifications determined by each participant at the beginning of the study did not play a large role in when or if participants decided to study on a particular day. The participants did not drop their current activity to study when the alarm went off. Instead, different participants adopted different strategies to study. Mrs. Green and



(a) Condition



(b) Gender

Figure 47: Words learned

Table 15: Locations where participants reported using SMARTSign

Participant	Location			
	Home	**Work**	**Car**	**Doctor's Office**
Mr. Orange				
Mrs. Gray	X			
Mrs. Green	X	X		
Mrs. Black	X			X
Mrs. Tiedye				
Mr. White	X			
Mrs. Ivory	X		X	
Mr. Brown	X		X	
Mrs. Yellow	X			
Mr. Purple	X	X		
Totals	8	2	2	1

Mrs. Yellow both said they just tried to study when they had free time. Mrs. Gray and Mrs. Ivory said they tried to study at the same time every day. Mrs. Gray studied when she went to bed. Mrs. Ivory studied when she and her husband, Mr. Brown, took her son to school. Mr. Brown took their son inside, and she sat in the car studying.

6.5.7 Collaboration

SMARTSign was deployed to four households where both parents were participants in the study. In the interviews, participants reflected on how that impacted their use of the system. In Mr. Orange and Mrs. Gray's household, Mr. Orange said that he and his wife quizzed each other constantly. He said that she made fun of him because his vocabulary was lower. Both Mr. Orange and Mrs. Gray and Mrs. Tiedye and Mr. White noticed that they had different vocabulary lists and reported learning not only some of their own vocabulary, but their partner's as well. Mrs. Tiedye and Mr. White actually exchanged phones when they were done studying for the day to see the other vocabulary. Two families: Mr. White and Mrs. Tiedye, and Mr. Purple and Mrs. Yellow, said that one person played the role of reminding the other to study.

Three participants talked about how SMARTSign had a role in how they interacted with their child. Mrs. Tiedye used the fact that she was learning signs for stories. When she and her son went to her mother's house every weekend, she would find the books she was learning to sign and sign with her son. While this was the goal of the *Stories* condition, Mrs. Tiedye was the only participant to seek the books out. Mr. Purple talked about using SMARTSign with his son. When he was feeding his son, he wanted to work on signs with him and got the application out. Mrs. Black looked up a number of signs in the SEARCH component. On Halloween, she looked up holiday-related words such as "trick," "treat," "witch," "ghost," and "zombie." She also started looking up fruits one day because her daughter wanted to know how to sign "avocado."

6.5.8 Using Story Vocabulary

Five participants were in the experimental condition with vocabulary organized around popular children's stories. As mentioned before, one participant actually sought out the stories to share with her son. Three of the other participants noticed the organization and liked it. Mrs. Black said it was a great idea and gave her "something good to compare to." Mr. Orange did not notice the organization and when asked about it in the final interview seemed surprised and excited.

Why did participants in the *Stories* condition use SMARTSign more? There are three possible explanations for this phenomenon. One possible explanation is that the stories provided a context for the learning material. Participants in the *Word Types* condition may have felt that they were learning words with no immediate context for use. Another explanation is that the books served as a "badge of completion." Once all the vocabulary of a particular book was studied, participants could say they finished something. However, completing all of the "Vehicle" words, or one of the other word themes, in the *Word Types* condition would be a comparable achievement.

A final explanation for the success of the *Stories* condition in comparison with the *Word Types* condition could be that learning the signs for a book might feel like a more accessible goal than the much larger task of learning ASL vocabulary. Further research could be done to investigate which explanation is more likely.

6.6 Analysis

In this section I analyze the learning results described in Section 6.5.4. First, I compare the results in the current study with those of Henderson-Summet. Second, I look at specific participants' logs to determine how their study behavior may have affected their learning results.

6.6.1 Comparison with Henderson-Summet

In this section, I will compare the results found in this study with those found by Henderson-Summet [43]. The study designs for these two studies are very different. Henderson-Summet's population consisted of college students with no known motivation to learn ASL, while this study's population consisted of parents with young children who are currently learning ASL or are interested in learning ASL for communication. Participants were asked to study 60 words a day in Henderson-Summet's study, while in this study participants were able to choose how many words to study and how often they wanted to study. While Henderson-Summet's study lasted one week, with a one-week forgetting period before testing, this study lasted four to six weeks. Participants were told they could stop studying at the end of four weeks, but were free to continue until the phones were returned up to a week-and-a-half later. This resulted in some participants "cramming" on the day of the post-test. Given all of these differences in study design, the data in this section must be interpreted very carefully.

Table 16: Comparison of study times from Henderson-Summet and current study

Condition	**N**	**Mean (in minutes)**	**SD**
H-S PD	10	453.9	422.5
H-S PM	10	516.8	557.9
H-S CD	10	91.0	31.6
H-S CM	10	114.5	85.0
All Participants	10	88.7	49.7
Stories	5	111.9	47.2
Word Types	5	65.5	44.6
Males	4	83.4	27.8
Females	6	92.2	62.8

Table 16 shows a comparison of the total time spent learning in Henderson-Summet's study and in the current study. Four conditions are listed for Henderson-Summet's study, *H-S PD*, *H-S PM*, *H-S CD*, and *H-S CM*. *H-S* denotes that this data comes from Henderson-Summet's research. Participants either used a phone (P) or a computer (C) to study. Lessons were either presented distributed (D) throughout the day, or were massed (M) into one session each day. The data from the current study is listed by: all participants, condition (*Word Types* or *Stories*), and gender (male and female). The participants in Henderson-Summet's phone conditions studied much longer on average than the participants in this study. The participants in the current study have total study times that are comparable to the computer conditions in Henderson-Summet's study. However, in this study, participants studied this amount over approximately four weeks as opposed to the one week allowed in Henderson-Summet's study design.

The participants in the current study had recognition and production scores that were comparable to Henderson-Summet's participants. Table 17 shows a comparison of the post-test scores between Henderson-Summet and the current study. Unfortunately, it does not appear that the introduction of the Recorder component improved participants' ability to produce the signs over that found in Henderson-Summet's study. The percentage of completely incorrect signs does appear to be

Table 17: Comparison of scores from Henderson-Summet and current study

	Condition	N	Mean	SD	Min.	Max.
Recognition Correct (%)	*H-S PD*	10	41	18.8	15	67.5
	H-S PM	10	63	14.5	35.9	90
	H-S CD	10	45.5	14.0	19.4	67.5
	H-S CM	10	47.4	16.7	20.0	72.5
	All Participants	10	67.42	14.88	50.00	97.22
	Stories	5	78.20	13.04	64.10	97.22
	Word Types	5	56.63	6.12	50.00	65.22
	Males	4	68.13	20.06	51.72	97.22
	Females	6	66.94	12.51	50.00	83.33
Production Correct (%)	*H-S PD*	10	21.8	10.5	7.5	35
	H-S PM	10	32.8	15.8	13.9	72.5
	H-S CD	10	25.8	16.0	5.0	62.5
	H-S CM	10	28.6	9.7	20.0	47.5
	All Participants	10	32.05	17.29	9.52	72.97
	Stories	5	40.04	19.68	22.50	72.97
	Word Types	5	24.05	11.20	9.52	37.50
	Males	4	36.81	24.94	16.22	72.97
	Females	6	28.87	11.60	9.52	42.11
Production Incorrect (%)	*H-S PD*	10	63.3	10.6	48.6	82.5
	H-S PM	10	45.3	17.3	12.5	77.8
	H-S CD	10	59.6	17.5	35.0	85.0
	H-S CM	10	58.4	13.5	35.0	75.0
	All Participants	10	35.83	20.91	16.22	90.48
	Stories	5	26.82	6.79	16.22	35.00
	Word Types	5	44.85	27.10	25.00	90.48
	Males	4	30.89	13.58	16.22	48.65
	Females	6	39.13	25.37	25.00	90.48

lower in the current study, however this could be due to differences in scoring between the two studies in determining what is incorrect and what is partially correct.

6.6.2 Interpretation of Usage Logs

The usage logs can help interpret some of the results from the vocabulary post-test Appendix H shows graphs of the participants' use of SMARTSign over the course of the entire study. Data is presented in the form of the number of activities in each component performed each day. In this section, I look at the logs of high- and

low-performers to see what study patterns may lead to successful learning.

Mr. White performed the best on both the recognition (97.22%) and production (72.97%) tests. His usage data is shown in Figure 53. Mr. White finished studying all of the new words on the seventeenth day of the study, which was also the day of his two week meeting. After learning all of the new words, his usage became much more sporadic. There were three main days when he used the recorder, each corresponding to one of the study meetings. On the day of the last meeting, his activity level spiked almost as high as the first day. It can be inferred from this data that his performance on the post-test was impacted by this final study session.

The next highest performing participant is Mrs. Gray with a recognition score of 83.3% and a production score of 42.11%, considerably lower than Mr. White's. Mrs. Gray's usage data is in Figure 49. Mrs. Gray finished studying all of the new words after day 14. She continued to study regularly until the 28th day. After four weeks using the system, participants were told their study requirement was over. She did some moderate studying on the day of the final meeting. Mrs. Gray recorded videos almost every day she studied.

Mrs. Black had the third highest recognition score of 77.78%, but the third worst production score of 22.50%. Her usage log looks very similar to Mrs. Gray's. She finished learning all of the new words on the 12th day and continued to study regularly throughout. Data from the interview and logs do not explain why the production scores for Mrs. Gray and Mrs. Black are so different. However, Mrs. Black had more words partially correct than Mrs. Gray, so the difference in production scores could be a matter of accuracy and not memory.

Participants seemed to be more motivated to use the system when they were learning new words. After they encountered all 80 words on their study list, participants studied less regularly. Mrs. Green is the most extreme example of this. Her usage data is shown in Figure 50. She switched the number of words to study per day

to unlimited and learned all of the words in the first day. She spent that day and the next signing all of the words on her list, after which she did not really use the application again. While her proportion of RECORDER to STUDY use is the highest of all of the participants, her lack of regular exposure to the signs led to fairly low recognition (56.76%) and production (30.56%) scores.

Mrs. Yellow had the lowest scores of all of the participants. She also knew the fewest signs at the beginning of the study, studied the fewest words, and gave SMARTSign a very low usability score. In the interview, Mrs. Yellow said that she thought SMARTSign would be easier to fit into her schedule than it was. She did not study any words until two weeks into the study and only scheduled herself to study five words a day. Mrs. Yellow spends most of her time at home caring for her child. When she did use the application she would miss the video in the quizzes and then be frustrated by having to select an answer anyway. Allowing learners to replay quiz videos may help the usability rating and ease frustration to increase use of the application for participants like Mrs. Yellow. However, Mrs. Yellow's child is also very young and has a cochlear implant. She might not have been as motivated to learn the signs as the other participants in the study who must rely on ASL to communicate. Mrs. Yellow's husband, Mr. Purple, performed slightly better. He could study at work with less distraction, and also seemed much more interested in learning ASL. He reported frustration with his son's progress using just the cochlear implant.

6.6.3 Sustaining Learning

Only two participants, Mrs. Black and Mr. Orange, continued using SMARTSign in the period between the end of their four weeks of study and the final meeting for the post test. The post-study questionnaire described in Section 6.4.1 included a question about how frequently participants felt they would use SMARTSign. This question is number 11 in the questionnaire found in Appendix G. For this question, five of the

participants said they "strongly agreed" that they would use SMARTSign frequently, four participants said they "agreed," and one participant, Mrs. Yellow, was "neutral." If participants said they would use SMARTSign frequently, why did so few continue using the application after it was no longer required?

SMARTSign is not the only intervention designed for independent language learning to experience a reduction in use over time [112]. The participants in Trusty and Truong's study interacted with the language learning tool less frequently in the second month of use. One reason the authors cited for the decrease in use was the static pool of vocabulary. Their participants had already seen most of the words, so they did not feel the need to continue practicing them. The participants in my study experienced a similar situation. Once participants had seen or signed all 80 words in their study list, there was less motivation to continue accessing the application. They would not be learning anything new. If participants had been able to continue learning more words beyond their own vocabulary list, participants might have continued using the application beyond the four weeks required.

In the full version of the application, a learner can study over a thousand signs. However, there needs to be a balance between new signs and review signs in order to make sure that learners actually review. There are a number of algorithms for presenting learning material [29, 43]. Incorporating Edge et al.'s "Adaptive Spaced Repetition Algorithm," which does not require a model of relative sign difficulty and is thus scaleable to the the size of the SMARTSign dictionary, would help encourage learners to review so they can earn new signs to study.

Another way to motivate learners to continue using the application is to incorporate game elements. Websites like Duolingo (http://www.duolingo.com) and Lingt (http://www.lingt.com) are two examples in this genre. Both websites incorporate levels. Learners increase their level by mastering words. Lingt incorporates achievements. One type of achievement is unlocked by studying daily. The achievement

is first unlocked after a few days of consistent study. Learners can continue to unlock levels of this achievement through increasing intervals of daily study. Duolingo connects to social networks. This allows learners to compete with their friends and also allows for learners to broadcast their accomplishments. Positive responses from friends about those accomplishments could encourage learners to continue making progress. SMARTSign could be adapted to incorporate these game elements.

6.7 Conclusions

Despite a small population size and messy data associated with conducting a study in the wild, with less experimental control than would be desirable for a quantitative study, conclusions can still be drawn from this study. Participant gender did not play much of a role in how they used the application. Despite the fact that the men knew significantly fewer signs than the women at the beginning of the study, there were no differences in how much they were able to learn from the application. Over the course of the study, all participants reported increased comfort levels with signing and recognizing the signs of others. They also signed more with others. However, participants did not increase the frequency of signing with their child. For the most part this seems to be because parents are already signing fairly frequently to their child. More emphasis on activities that encourage parents to sign with their children could help increase the frequency that parents sign with their child. Only one participant actually used the stories she was learning to sign with her child.

Participants in the *Stories* condition improved their recognition of ASL words more than participants in the *Word Types* condition. Their comfort levels with recognizing Deaf adults' signs also increased more than for participants in the *Word Types* condition. This is most likely because participants in the *Stories* condition spent more days using the application and more total time using the STUDY component in the QUIZ format. The *Stories* condition did not affect the participants' ability

to produce the signs over the participants who were in the *Word Types* condition.

Two factors may have contributed to the overall low production scores. The first factor consists usability issues with the RECORDER. If participants had been provided with stands to hold the phone, they may have been more willing to practice signing and create videos. Participants did not feel uncomfortable seeing themselves in the camera, but instead just had difficulty creating good videos of their signs. Learners should also be asked if they are in an environment where they are free to sign. When they could not sign, participants got frustrated when the application kept asking them to record.

The second factor that could explain low overall sign production scores is that most participants stopped studying as frequently once they had seen all of the new words. When they did not study as frequently, they did not get the review that is necessary to move from recognition to production. The lack of review may have been due to frustrations from the RECORDER component which was sometimes activated during review. The data from Mrs. Green indicates that once participants learned all of the signs, they were less motivated to practice even if they did sign them using the RECORDER. The SMARTSign application could be improved by helping learners better assess their mastery of the signs. In the current version, if a word was signed, then it was checked off of the REPORT CARD component. Mrs. Green had seen and signed all of her vocabulary and thus her REPORT CARD was at 100%, however the perfect score does not mean that she actually learned all of the signs. If learners were asked to give their sign a score after recording it, the REPORT CARD would better reflect how well an individual sign has been learned and this information could also be used when the application is determining what sign to present in the STUDY component. If learners do not want to use the RECORDER component, they can be asked to think how to produce the sign and use that for the rating.

SMARTSign was well-received by the participants in the study and many asked

to be notified when the application is released. Using SMARTSign, participants were able to increase their ASL vocabulary comprehension, but because production scores did not improve, overall language learning was not improved. With the improvements suggested above, SMARTSign could become a popular tool for hearing parents attempting to learn ASL.

CHAPTER VII

FUTURE WORK

In this chapter, I build on the results presented in Chapter 6 by exploring limitations of this thesis work and make recommendations for future work based on the discussion presented in Section 6.7.

7.1 Limitations

In this section, I discuss threats to the internal, external, and construct validity of the three studies presented in this thesis. While each study had different designs and populations, in order to evaluate the impact of the thesis, it is useful to discuss the limitations as a whole. For the purposes of this chapter, these three studies will be referred to as the video resolution study (Chapter 3), the interview study (Chapter 4), and the deployment study (Chapter 6).

7.1.1 Internal Validity

Internal validity refers to how well the changes in the dependent variables can be explained by the manipulation of independent variables. The biggest threat to internal validity in this thesis is group composition effects. The number of participants recruited for all of the studies was relatively small. When study populations are small, variations in individual performances have a large impact of the dependent variable. It is difficult to balance for all possible variations in participants. In the video resolution study, there was no threat because each participant experienced all of the experimental conditions. In the interview study, there were no experimental groups. For the deployment study, group composition effects could have occurred

because I used a between-subjects study design. I balanced the two groups for gender and number of participants in the household. However some participants were attending ASL classes in addition to their participation in the study. There were two participants who mentioned a class in the *Stories* condition and one participant in the *Word Types* condition. Their ASL classes may have had an effect on their ability to learn signs over the course of the four-week study. However, there was not a great disparity in the number of participants taking classes between the two groups.

7.1.2 External Validity

External validity refers to the extent that findings from research can be generalized to other situations and people. The two possible threats to external validity are non-representative sampling and nonrepresentative research context. As discovered in the deployment study, the conclusions from the video resolution study suffered from non-representative sampling. Both studies had participants reproducing signs from videos displayed on mobile phones, but the effect of video quality led to different reactions from the two populations. In the video resolution study, the participants were not from the target population. Participants mentioned wishing they could see the video again or at a slower speed, but they had high reproduction scores. Participants in the deployment study had difficulty remembering signs and reported not feeling comfortable enough to even try to reproduce the signs. It appears that the cost of signing incorrectly is much higher for people who actually need to learn the signs to communicate. The interview and deployment studies had more representative sampling. Participants for these two studies were recruited from the target population of hearing parents with deaf children. In the interview study I recruited participants from all over the country to better represent the experience of parents all over the country. The level of support received by parents varies from county to county based on the state and local services available. In the deployment study, I recruited participants

from a smaller geographic region, so there may be a sampling bias. However, I still managed to obtain participants who received different levels of support for learning ASL. Therefore, the third study still had representative sampling of the entire US population of hearing parents learning ASL.

The video resolution study did not have a representative research context. It was a laboratory study and participants did not experience interruptions while viewing the sign videos. In the interview study, the nonrepresentative research context was less of a detriment. In the deployment study, I attempted to study in a representative research context. Participants used the application for four weeks in their own homes during their daily lives. Giving participants a new phone to use was the only part of the experiment that was nonrepresentative of their daily routine. While I tried to get participants to use the provided phone as their primary phone, this was not feasible for most of the participants. However, I still found evidence of parents incorporating the phone and application into their daily routine. The length of the study suggests that behavior in the latter weeks of the study could be generalized to longer term use of the application for learning ASL. The conclusions on the role of notifications in deciding when to study is the weakest in terms of the nonrepresentative context of the deployment study.

7.1.3 Construct Validity

Construct validity refers to the quality of the forms of the independent and dependent variables. The Hawthorne effect is one example of a threat to construct validity. The Hawthorne effect refers to the effect that participating in a research experiment has on participant behavior [75]. Merely studying a phenomenon can impact the strength of that phenomenon. The Hawthorne effect could have had a negligible impact on the video resolution study. Participants knew they were being tested on accuracy and reproduced the signs at a high level of accuracy across all of the conditions. I believe

the impact is negligible because all participants in the video resolution study experienced all of the possible conditions. The purpose of the study was to determine if video resolution affected participants' ability to reproduce the signs accurately. If the videos were not detailed enough, participants would not have been able to reproduce the signs with such high accuracy. In the interview study, the Hawthorne effect may have impacted how well SMARTSign was received, but I was still able to gain insight into how parents learn ASL currently and what difficulties they have. I was also received advice on ways to improve the application. The deployment study could have suffered from the Hawthorne effect, however, participants in both conditions used the application and would be subject to anxiety about learning the signs. Participants in the *Stories* condition still used the application more and performed better than participants in the *Word Types* condition. The fact that participants did not even follow the request to study a minimum of four times a week is an indicator that the Hawthorne effect did not play a large role in the results found in the deployment study. If participants were worried about the post-test evaluation and their usage being tracked to determine compliance, I would have seen more regular patterns of use across all of the participants.

Experimenter expectations can also play a role in reducing the quality of the independent variable as described by the Rosenthal effect [75]. While I believed that the medium resolution video condition in the video resolution study would still be sufficient for reproducing video, I did not expect the low resolution video to receive high scores as well. The interview study may have been more susceptible to the Rosenthal effect. While some participants brought up the idea of learning to sign stories in ASL, all participants were asked about this possibility. What convinced me to continue with the story signing motivation was the negativity expressed by many parents regarding the other proposed methods. In order to avoid the Rosenthal effect in the deployment study, I created a strict procedure for the first meeting.

When introducing the Report Card component of the SMARTSign application, I pointed out the organization, whether *Stories* or *Word Types*, but did not suggest how participants use this information. I did not suggest that participants in the Stories condition actually seek out the stories, nor did I ask about their familiarity with those stories. One participant did seek those stories out over the course of the study. Overall, I attempted to foresee threats to validity in this thesis and avoid them wherever possible.

7.2 Future Work

There are two main areas for future work in this thesis: improvements to the SMARTSign application and open areas for further investigation.

7.2.1 Improving SMARTSign

While improvements to SMARTSign were discussed in Section 6.7, they will be summarized again here. The Recorder component was not employed as much as expected and production scores were lower than hypothesized. Reasons why participants did not use the component include difficulty recording, lack of confidence in knowledge of the sign, and general lack of review. Providing learners with a stand for the phone and encouraging them to visualize how to perform the sign when they are in environments not conducive to signing will help learners to concentrate on sign production. Enabling the slow motion playback of videos and allowing learners to replay videos during the Quiz when they were missed will help improve learners' confidence in their knowledge of how to perform the sign. By slowing the introduction of new signs to allow learners to master previously seen signs, they will be encouraged to use the system longer. The version of the SMARTSign used in the final study allowed participants to learn all of the new signs at the beginning and did not provide a mechanism for them to evaluate their knowledge of that sign. Balancing the presentation of new signs versus review signs by incorporating Edge et al.'s "Adaptive Spaced

Repetition Algorithm" [29] will remove the possibility of learners studying only new signs. Having learners rate either their performance of a sign or their visualization of the sign and using that rating in the Report Card will make participants better aware of their current progress in learning a particular sign. By making these changes learners will hopefully use the Recorder more often and review their signs so that they can move beyond recognition and learn how to produce the signs.

7.2.2 Future Research

In Section 7.1.1, I discussed the possibility that taking ASL classes in parallel with using SMARTSign may have impacted the results of the third study. One area for future research is how the SMARTSign application can be integrated into the class environment. Can using SMARTSign in tandem with classroom instruction improve knowledge of ASL vocabulary over classroom instruction alone?

A second area for future research is to determine whether it is possible to design a version of SMARTSign to provide support for parents for whom English is a second language. In many communities there there is a need for resources for Hispanic families with deaf children. Nationally, there are a growing number of deaf and hard of hearing children from Latino families (29%) and families where Spanish is the primary language (22%) [35]. In some states, these numbers are even higher. For example, in Texas the percentage of Spanish-speaking families of deaf and hard of hearing children is 31.5%, and in California that number is 45.5% [35]. These families might be better served by an application written in Spanish rather than English. Are the findings from the research presented in this thesis also applicable to Hispanic parents?

CHAPTER VIII

CONCLUSION

The research in this dissertation was conducted with the goal of supporting the following thesis statement: *Hearing parents of deaf children want to learn American Sign Language (ASL) for a number of reasons, but they are frequently unsuccessful. One common activity that hearing parents regret not experiencing with their deaf children is reading books together. Providing a method for parents to learn and practice ASL words associated with popular children's stories on their mobile phones will help improve their ASL ability. Parents who are given a vocabulary list designed for learning to sign stories will access the application more often which will lead to more exposure to ASL and more learned vocabulary than parents whose vocabulary list is designed around word themes.*

The work in this dissertation has supported the hypothesis that structuring an application around learning vocabulary for popular children's stories does lead parents to access the application more often than when the application is just structured around communication. Parents who studied story vocabulary recognized more signs than parents who studied general vocabulary. However, the application condition did not change parents' ability to produce the signs. The hypothesis was partially correct. Participant comprehension was improved but not overall learning.

In the process of developing the SMARTSign application, I conducted two formative studies. In the Video Study, I explored the effect of manipulating resolution of ASL sign videos on novice signers' ability to reproduce those signs. The study showed that even in conditions with deeply degraded video, participants were still able to reproduce the signs with a high level of accuracy. Providing a video inset

with handshapes created a distraction to participants, therefore I did not pursue this method of video presentation in the design of the SMARTSign application. Reproduction scores for participants in the Video Study were fairly high across all conditions.

To better understand the methods hearing parents of deaf children currently use to learn ASL, I conducted an interview study. Hearing parents of deaf children should be highly motivated to learn ASL as it is the most accessible means of communication for their children. However, ASL is a difficult language, and hearing parents do not often succeed in learning it. I found that the participants preferred learning signs from videos more than from static images in books. Participants also liked learning organized around themes, and reported being most successful when learning was based on their immediate needs rather than on the abstract goal of language mastery. When asked about different ways of delivering new vocabulary content, parents responded most positively to the goal of learning vocabulary organized around children's stories.

After determining that mobile phones could present ASL videos in sufficient detail to be reproduced by novice ASL learners, and exploring the factors that could help hearing parents succeed when using an ASL learning application, I finalized the design of the SMARTSign application. SMARTSign consists of three main components: Search, Study, and Recorder. These three components are designed to facilitate both "push" and "pull" delivery of study material.

I deployed a study to evaluate how well parents could learn ASL vocabulary over a four-week period using the SMARTSign application. This study found that parents using the application to learn vocabulary associated with children's *Stories* learned to recognize more signs than participants learning vocabulary around *Word Types*. With the improvements suggested by the results of the deployment study, SMARTSign could become an effective tool for hearing parents attempting to learn ASL for their young deaf children.

APPENDIX A

SUMMARY OF MOBILE LANGUAGE LEARNING RESEARCH

Paper or *Project Name*	Learners			In Target Language Environment	Reason for Use			Duration
	Children	University Students	Adults		Lab or Single Session	Class	Self-Motivated	
ALEX [72, 84]			✓	Y		✓		6 months
AMICITIAS [96]		✓		Y	✓			exploring town
Ally et al. [4]			✓	Y		✓		86 lessons
CAMCLL [2]		✓		Y		✓		1 semester
Chen & Chang [21]		✓		N	✓			visit to zoo
Chen & Chung [20]		✓		N		✓		5 weeks
de Jong et al. [25]		✓		N	✓			30 minutes
Gromik [39]		✓		N		✓		14 weeks
Gu et al. [40]		✓	✓	N	✓			one session
Jain et al. [51]	✓			N		✓		4 weeks
Kiernen & Aizawa [56]		✓		N		✓		3 weeks
Liu & Chu [69]	✓			N		✓		8 weeks
LOCH [88]		✓		Y	✓			undefined
Lu [70]	✓			N		✓		2 weeks
MemReflex [29]			✓	Y			✓	3 weeks
MicroMandarin [30]			✓	Y			✓	4 weeks
MOBO City [33]		✓		N	✓			1 session
Move Idioms! [121]	✓			Y				3 months-1 year
Oberg [87]		✓		N		✓		school quarter
Pearson [92]			✓	Y		✓	✓	10 weeks
Saran et al. [99]		✓		N		✓		10 weeks
TenseITS [24]		✓		Y			✓	undefined
Thornton & Houser [108]		✓		N		✓		2 weeks
TipTapTones [28]			✓	Y			✓	3 weeks

APPENDIX B

INTERVIEW STUDY QUESTION LIST

B.1 Family structure

- How many children do you have?
- How old is your deaf child?
- Do you have any other deaf relatives?
- How does your family communicate with your child?
- What communication method do you use?
- Does your child have a sensory device? Cochlear implant or hearing aid?
- When was your child's deafness identified?

B.2 Current learning methods

- What was the reason for your decision to learn ASL?
- When did you decide to learn ASL?
- How long have you been learning?
- What strategies do you use currently to learn ASL?
- Are there any tools you have that you take everywhere with you?
- Do you use books, DVDs, computer programs, classes or phone applications?
- Describe your experience with each of the learning methods you use

- If you could make changes to your current learning methods what would they be?
- If you attend a class, how often does the class occur?

B.3 Prototype reactions

- For each of the three prototype versions I show you:
  - What do you think of this prototype?
  - What do you think it could be used for?
- What would you like to see in a system to help you learn ASL

B.4 Phone ownership

- What kind of phone do you currently own?
- What is your carrier?
- Are any other carriers available in your area?
- Do you have a data plan?
- Have you considered getting a data plan?
- If you had a system for your phone that could help you learn ASL would you purchase a data plan?
- If we provided you with a phone and data plan for the duration of a study (on the order of 1-6 months) would you be willing to participate in a future study testing such a learning system?

APPENDIX C

VOCABULARY SORTED BY WORD TYPE

Action Words

afraid
ask
away
began
begin
belong
bet
bit
bite
blame
blast
blew whistle
blow a bubble
blow air
break
bring
bring me
build
bump
bump into
buy
call (name)
call (summon)
call (yell)
came
came after (follow)
care
carry
catch
change
chase
chat
choose
clap
clean
climb
close
come
cook
cover
cried
crouch
cry
cut
dance
decide
did not know
did not like
die
dig
does not want
doesn't know
drag
drank
draw
drink
drive
drop
drown
dry
dump
eat
enter
escape
fall
fasten
fear
feed
feel
fell
felt
find
finish
fit
fix
flew (like a bird)
fly (like a bird)
fly (through the air)
follow
forget
forgot
found
gasp
gave
get
get a shot
get away from
get up
give
glare
go
got
grow
growl
guess
guess (suppose)
had
hang
hate
have
hear
help
hide
hit
hold
hop
hope
hug
hurry
jump
keep
kick
kill
kiss
knew
knock
know
lead
learn
leave (abandon)
leave (go)
left (abandon)
left (go)
let
lick
lift
like
listen
live
look
look like
love
made
make
measure
meet
met
mind
move
open (general)
open a can
open a door
open a jar
open a window
open eyes
open soda
own
paid

paint
pat
peel
pick
pick on
pile
play
please (make happy)
pour
pretend
promise
pull
push
put
put down (drop)
ran
reach
read
relax
rest (relax)
return (bring back)
ride (in a vehicle)
ride a bike
ride a horse
ride in a car
rip
rose (direction)
rub
run
said
sale
sat
saw
say
scare
scratch
search
see
send
shake
share
shook
shout
shouted
show
sigh
sign (language)
sing
sink (fall)
sit
skate
sleep
slide
smile
sneeze
snort
somersault
sound (call)
spill
splash
stand
start
stay
stop
sweep
swim
swing
take
take a pill
take back (return)
talk
taste
teach
tear
tease
tell
think
thought
throw
tickle
tie
told
took
touch
tried
visit
waiting
wake
wake up
walk
wash
washed
watch
weep
went
wipe
wish
wonder
work
wreck
write
yell
yelp

Animals

alligator
animal
ant
antler
bark (like a dog)
bear
beaver
bee
bird
bug
bunny
butterfly
cat
chicken
claw
cow
deer
dinosaur
dog
donkey
duck
elephant
fish
fly (insect)
fox
frog
giraffe
goose
hen
horns (antlers)
horse
kitten
kitty
lamb
lion
monkey
moose
mouse
owl
penguin
pet
pig
pony
possum
pup
puppy
rabbit
reindeer
rooster
sheep
skunk
snake
spider
squirrel
tail
teddy bear
tiger
turkey
turtle
whale
wolf
zebra

Body Parts

ankle
arm
back (body)
bellybutton
boo boo
bottom
butt
buttocks
cheek
chin
ear
elbow
eye
face
feet (bodypart)
finger
fingernail
foot (bodypart)
hair
hand
head
headache
injury
knee
leg
lips
mouth
nose
owie
pain
penis
shoulder
stomach
thumb
toe
tongue
tooth
tummy
vagina

Clothing

bead
belt
boot
button
clothes
coat
collar
diaper
dress
earring
glasses
gloves
hat
hearing aid
jacket
jeans
mittens
necklace
pajamas
pants
PJs
sandal
sandals
scarf
shirt
shoes
shorts
slipper
sneaker
snowsuit
sock
socks
stocking
sweater
swimsuit (boy)
swimsuit (girl)
tights
underpants
underwear
watch (wrist)
wear
wristwatch
zipper

Connectors

although
and
because
but
however
if
suppose

Descriptives

alas
all gone
all right
alone
angry
asleep
awake
bad
bare
best
better
big
black
blue
bored
boring
broken
brown
busy
careful
carefully
circle
cold
cool
crazy
cute
dark
deaf
deep
delicious
different
difficult
dirty
easy
empty
exciting
expensive
fast
fat
fine
first
full
fun
funny
gentle
glad
gone
good
green
half
happy
hard (difficult)
hard (not soft)
heat
heavy
high
hot
hungry
hurt
in back of (blame)
joy
knack
lame
large

last
least
life
like (resemble)
little
living
long
lost
loud
mad
mess
mistake
naughty
new
nice
nicest
noisy
okay
old
out of your head
peculiar
perfect
pink
poor (lousy)
poor thing
pretty
purple
quiet
ready
red
right (perfect)
sad
scared
shame
sick
silly
size (measure)
sleepy
slow
slowly
small
soft
special
speed
spot (circle)
sticky
straight (directly)
stuck
sudden
talent
tall
tame
thirsty
tiny
tired
tremendous
upset
useful
violet
well (good)
wet
white
windy
wrong
yellow
yucky

Food & Drink

apple
applesauce
bagel
banana
bean
bread
butter
cake
candy
carrot
cereal
cheese
chocolate
coffee
Coke
cookie
corn
cracker
cream cheese
donut
egg
food
french fries
grape
green beans
gum
hamburger
hot dog
ice
ice cream
Jello
jelly
juice
lemon
lollipop
meat
melon
milk
muffin
noodles
nut
orange
pancake
peanut
peanut butter
peas
pickle
pizza
pop
popcorn
popsicle
potato
potato chips
pretzel
pudding
pumpkin
raisin
salad
salt
sandwich
sauce
soda
soup
spaghetti
strawberry
syrup
tea
toast
tomato
tuna
vanilla
vegetable
vitamin
waffle
water
watermelon
yogurt

Furniture & Rooms

basement
bathroom
bathtub
bed
bedroom
bench
chair
closet
couch
crib
door
downstairs
drawer
dryer
floor
fridge
furniture
garage
hall
highchair

kitchen
living room
mattress
mirror
oven
playpen
porch
potty
refrigerator
rocking chair
room
shower
sink (water)
sofa
stairs
stove
table
television
toilet
TV
upstairs
washer
washing machine
window

Games & Routines

baseball
basketball
bath
birthday
bowling
breakfast
brush hair
bye
bye bye
call
call on phone
chores
dinner
don't
dressed
football
give me five
go potty
golf
good night
good-by
goodbye
hello
hi
high five
hush
I love you
let's see
look around
lunch
meeting
nap
no
patty cake
pee
peek-a-boo
please
poop
shh
shopping
shush
snack
song
tennis
thank
thank you
thanks
tire
turn around
wait
want
wash (face)
wash (hands)
yes

Helping Verbs

can (able)
can't
cannot
did
do
do not
does
don't know
don't like
don't want
going to
gonna
got to / gotta
have to / hafta
lemme
let me
lets me
maybe
might
must
need
need to
perhaps
should
try
will

Household Items

Band-Aid
bandage
basket
bell
blade
blanket
bottle
bowl
box
broom
brush
bucket
camera
can (container)
cent
chain
chapter
clock
coin
comb
computer
cup
dish
fork
garbage
glass
gun
hammer
jar
key
Kleenex
knife
ladder
lamp
letter
light
material
medicine
money
mop
nail
napkin
net
newspaper

pail	purse	stuff (things)	trash
paper	radio	stuffing	tray
pen (writing tool)	rope	tape	TTY
penny	scissors	telephone	vacuum
picture	soap	thing	walker
pillow	something	tin can (bucket)	word
pistol	spoon	tissue	
plant	stamp	toothbrush	
plate	string	towel	

Letters & Numbers

0	letter A	letter L	letter W
1	letter B	letter M	letter X
2	letter C	letter N	letter Y
3	letter D	letter O	letter Z
4	letter E	letter P	one
5	letter F	letter Q	six
6	letter G	letter R	three
7	letter H	letter S	two
8	letter I	letter T	
9	letter J	letter U	
four	letter K	letter V	

Outside

air	garden	pen (fence)	snow
backyard	grass	pit	snowman
barrel	ground	plow	sprinkler
bone	highway	rain	star
chimney	hill	rock	stick
cloud	hole	roof	stone
dirt	hose	sand	street
feather	lake	sandbox	sun
fence	lawn mower	shade (shadow)	tent
field	lightning	shed	tree
fire	moon	shovel	wall
flag	mud	sidewalk	wind
flower	nest	sign (display)	yard
forest	outdoors	sky	

People

aunt	brother	cowboy	everyone
baby	child	dad	family
babysitter	clown	daddy	farmer
barber	cousin (female)	doctor	father
boy	cousin (male)	everybody	fireman

firemen	lady	no one	sister
friend	mailman	nobody	somebody
girl	man	nurse	teacher
grandfather	master	papa	uncle
grandma	mom	people	woman
grandmother	mommy	person	
grandpa	monster	police	
indian	mother	policemen	
kid	nana	Santa Claus	

Places

bank (building)	downtown	park	synagogue
beach	farm	party	temple
building	gas station	picnic	town
camping	home	place	woods
castle	house	playground	world
church	jail	restaurant	zoo
circus	McDonald's	school	
city	mosque	shop	
country	movie	store	

Prepositions & Locations

about	between	into	through (into)
above	by (next to)	low	to
across	by (past)	near	top
all about	bypass	next to	toward
all over	down	off	under
around	for	on	up
at	front	out	way
back (return)	here	over	with
back of	in	right (directly)	
behind	in front	right up to (directly)	
beside	inside	there	

Pronouns

he	its	that	us
her	me	their	we
hers	mine	them	you
him	my	these	your
his	myself	they	yourself
I	our	this	
it	she	those	

Quantifiers & Articles

a lot (many)	both	many	other
a lot (much)	each	more	really
all	else	most	rest (what's left)
almost	every	much	same
already	everywhere	no (none)	some
also	feet (measurement)	none	too
another	hundred	not	very
any	instead	numbers	
at least	just	only	

Question Words

how	What are you doing?	What is it doing?	who
what	What could I do?	What is she doing?	why
What are they going	What do?	when	
to do?	What for?	where	
What are we doing?	What is he doing?	which	

Time

after	happen	once	tonight
again	later	soon	twelve o'clock
always	morning	still	until
at last	never	suddenly	week
before	next	summer	while
day	night	then	winter
ever	noon	time	yesterday
finally	not yet	today	
forever	now	tomorrow	

Toys

ball	clay	kite	story
balloon	crayon	microscope	toy
bat (baseball)	doll	pencil	wagon
block	drum	Play-Doh	whistle
book	game	present	
bubble	gift	puzzle	
chalk	glue	robot	

Vehicles

airplane	car	sled	truck
ambulance	firetruck	stroller	
bicycle	helicopter	tractor	
boat	motorcycle	train	
bus	plane	tricycle	

APPENDIX D

VOCABULARY SORTED BY BOOK TITLE

A Fly Went By

a lot (much)
after
again
all
another
ask
away
bad
bank (building)
big
bite
by (next to)
by (past)
came after (follow)
cat
come
cow
deaf
did not know
do not
doesn't know
dog
don't want
down
fast
fat
fear
feet (measurement)
fly (insect)
fox
frog
get
get away from
go
gone
good-by
gun
had
hall
have
he
head
hear
help
here
hill
him
hit
hop
house
I
in
in back of (blame)
jump
kick
kill
know
lake
lame
last
like
little
look
mad
made
man
me
must
my
near
never
no
no one
not
now
off
one
other
out
out of your head
pick on
pig
put down (drop)
ran
red
run
said
sat
saw
see
shake
shame
she
shed
sheep
shook
sky
stop
tall
tame
tent
that
they
thing
this
tin can (bucket)
told
took
town
two
up
wall
want
well (good)
went
what
What could I do?
when
why
yell
you

Are You My Mother?

away
baby
big
bird
boat
but
by (next to)
car
cow
did not know
dog
down
eat
egg
find
get

go
have
have to / hafta
he
hen
her
here
home
how
I
jump
kitten
look
mother
must
my
no
not
now
old
on
out
plane
ran
said
sat
saw
she
stop
then
there
tree
up
walk
want
went
what
where
who
will
yes
you

Go, Dog. Go!

again
all
and
around
away
back (return)
big
black
blue
boat
call (summon)
car
day
do not
dog
don't like
down
fast
fly (through the air)
four
fun
get up
get up
go
good-by
green
hat
hello
here
hot
house
I
in
into
keep
light
like
little
live
look
night
not
not
now
on
one
one
out
over
party
place
play
red
should
sleep
some
spot (circle)
stop
sun
that
there
they
thing
those
three
three
time
to
top
tree
tree
two
two
under
up
very
wall
water
way
what
What are they going to do?
where
white
why
work
yellow
you

I Wish that I Had Duck Feet

about
again
air
all
and
apple
away
bad
ball
bank (building)
bet
better
big
blow air
book
brown
bus
but
car
carry
catch
cool
dad
day
does not want
don't
door
down
dry
duck
eat
elephant

else	if	out	tennis
every	in	paper	thanks
eye	inside	pen (writing tool)	there
feel	instead	play	these
feet (bodypart)	jump	policemen	thing
feet (measurement)	just	pull	think
fire	keep	put	this
firemen	kid	ride (in a vehicle)	tie
floor	know	right (perfect)	town
fly (insect)	like	rope	tree
fun	long	sad	two
girl	love	say	up
good	man	scare	very
grow	me	school	visit
guess	more	see	wash
had	mother	shoes	watch
hat	my	show	way
have	net	size (measure)	wear
head	never	sneeze	whale
heat	new	some	what
help	night	splash	when
high	no	stop	which
hit	nobody	store	who
hope	nose	street	why
horns (antlers)	not	string	window
hose	now	stuff (things)	wish
hot	off	summer	with
house	on	tail	work
how	one	take	you
hundred	only	teacher	zoo
I	other	tell	

It's Not Easy Being a Bunny

all	don't want	home	mud
bear	ear	hurry	not
beaver	easy	in	only
big	eat	least	pig
bird	every	leave (go)	possum
brother	everyone	like	really
bunny	exciting	live	sad
call (yell)	fly (like a bird)	living	said
care	funny	made	see
carrot	hang	make	sister
cook	happy	many	sit
day	headache	moose	skunk
decide	him	most	sleep
did not like	his	mother	them

thing	want	winter	
tried	went	with	
very	when	work	

Little Monster

all about	everybody	in	shout
and	fast	jump	they
behind	friend	little	wait
big	go	monster	where
cake	happy	out	with
chapter	he	party	yell
couch	hide	ready	
day	his	run	

Put Me in the Zoo

air	here	orange	violet
all	high	out	want
and	I	put	we
ball	if	say	what
blue	into	see	when
box	it	small	where
can (able)	like	sock	why
cat	look	stay	will
circus	make	take	wish
do	me	tall	with
do not	more	tell	yes
go	my	them	you
good	new	there	zoo
green	now	this	
hat	on	up	

Ready, Alice?

beach	egg	hungry	net
bite	face	I	nice
boat	father	it	not
breakfast	fork	jeans	not yet
call (yell)	found	juice	off
careful	get	later	on
dad	go	like	pail
day	good	look	pistol
don't	got	mess	put
downstairs	hand	mom	ready
drank	hat	morning	said
dressed	her	mother	sandals
eat	hit	my	she

shirt
shoes
shorts
shouted
shovel
six
socks
sun
take
time
toast
took
top
up
upstairs
waiting
want
washed
water
we
went
what
you

The Best Nest

again
all
all right
already
always
another
around
ask
barrel
bell
belong
best
big
bird
broom
brown
build
bump into
busy
but
carry
cat
change
chimney
church
come
cry
dark
day
down
eat
egg
else
every
everywhere
face
fast
fat
feather
find
finish
first
flag
flew (like a bird)
foot (bodypart)
forever
gasp
got
guess (suppose)
hair
happy
hard (difficult)
hate
her
here
high
horse
house
in
inside
into
it
left (abandon)
like
look
love
low
make
man
many
mattress
maybe
mess
mind
mistake
morning
mother
mouth
move
my
near
need
nest
never
new
next
nice
nobody
not
now
off
old
open (general)
out
pick
place
pretty
pull
rain
red
rest (relax)
rest (what's left)
roof
rope
said
see
she
sing
sit
smile
soda
somebody
something
song
stay
stocking
stop
string
stuffing
sweater
take back (return)
then
there
they
thing
this
thought
tired
took
top
twelve o'clock
under
until
up
water
went
when
where
work
world
wrong
you

The Digging-est Dog

a lot (many)
above
across
air
alas
all over
almost
alone
always
and
animal
apple
around
at
at last
at least
away
back (body)
back (return)
bad
barber
bare
bark (like a dog)
because
before
began
behind
beside
big
bit
blast
blew whistle
bone
both
brown
building
but
call (name)
came
cannot
careful
carefully
chain
chair
chin
chores
claw
collar
cried
crouch
day
deep
die
dig
dirt
dog
door
down
drag
drown
each
ear
elbow
ever
every
eye
face
farm
fast
fell
felt
fence
fix
floor
four
friend
full
fun
garden
gave
get
glad
glare
good
grass
green
ground
growl
half
hand
happy
hard (difficult)
hard (not soft)
he
head
hear
help
hen
here
hide
highway
hill
him
hole
house
how
hurt
I
if
in
in front
inside
instead
jail
joy
just
knack
knew
knock
lead
learn
left (go)
let
lets me
life
lift
like (resemble)
live
living
long
look
make
man
many
master
maybe
me
meeting
met
more
morning
mud
my
myself
need
never
next
nicest
night
no (none)
no one
nose
now
okay
on
once
one
only
other
out
outdoors
own
paid
pain
pat
pen (fence)
pet
pick
pig
pile
pit
place
play
please (make happy)
plow
pretty
pull
pup
reach
right (directly)
rooster
rose (direction)
rub
run
sad
said
sale
sand

saw
say
scratch
see
send
shade (shadow)
sheep
shop
shout
show
sigh
sign (display)
sink (fall)
sit
six
sky
sleep
slowly
smile
soft
some
special
speed
stand
start
still
stone
stop
store
straight (directly)
stuck
sudden
suddenly
summer
sun
take
teach
tell
thank
that
then
think
through (into)
tie
to
today
toe
too
took
top
touch
toward
town
tree
tremendous
tried
try
up
us
useful
walk
want
watch
water
way
we
went
what
when
where
while
whistle
white
why
will
window
with
wonder
word
wreck
yelp
you

APPENDIX E

PARTICIPANT VOCABULARY

Summary Table of pre-known and studied vocabulary. The K column indicates the participant already knew the word. The S column indicates a word on the participant's study list.

Word	02Orange		03Gray		04Green		05Black		06Tiedye		07White		08Ivory		09Brown		10Yellow		11Purple		Totals		
	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	Both
beside, by (next to), next to		X		X		X		X		X		X		X		X		X		X	0	10	10
but, however		X		X		X		X		X		X		X		X		X		X	0	10	10
chapter		X		X		X		X		X		X		X		X		X		X	0	10	10
everybody, everyone		X		X		X		X		X		X		X		X		X		X	0	10	10
hen		X		X		X		X		X		X		X		X		X		X	0	10	10
hide		X		X		X		X		X		X		X		X		X		X	0	10	10
his, hers, its		X		X		X		X		X		X		X		X		X		X	0	10	10
monster		X		X		X		X		X		X		X		X		X		X	0	10	10
yell, shout, shouted, call (yell), yelp		X		X		X		X		X		X		X		X		X		X	0	10	10
behind, back of		X		X	X			X		X		X		X		X		X		X	1	9	10
cake		X		X	X			X		X		X		X		X		X		X	1	9	10
everywhere, all about, all over		X		X	X			X		X		X		X		X		X		X	1	9	10
he, her, him, it, she		X		X		X	X			X		X		X		X		X		X	1	9	10
here		X		X		X	X			X		X		X		X		X		X	1	9	10
ready		X		X		X		X		X	X			X		X		X		X	1	9	10
say		X	X			X		X		X		X		X		X		X		X	1	9	10
take, took		X	X			X		X		X		X		X		X		X		X	1	9	10
then		X		X	X			X		X		X		X		X		X		X	1	9	10
and		X		X	X		X			X		X		X		X		X		X	2	8	10
away		X		X	X			X		X		X	X			X		X		X	2	8	10
big, large		X	X			X	X			X		X		X		X		X		X	2	8	10
couch, sofa		X		X	X			X	X			X		X		X		X		X	2	8	10
did, do, does		X		X	X		X			X		X		X		X		X		X	2	8	10
find, found		X		X		X		X		X	X		X			X		X		X	2	8	10

Continued on next page

Word	02Orange		03Gray		04Green		05Black		06Tiedye		07White		08Ivory		09Brown		10Yellow		11Purple		Totals		
	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	Both
get, got		X		X		X	X		X			X		X		X		X		X	2	8	10
party		X		X		X		X	X		X			X		X		X		X	2	8	10
these, them, they, those		X		X		X	X			X		X		X	X			X		X	2	8	10
this		X		X	X			X	X			X		X		X		X		X	2	8	10
wait, waiting		X		X		X	X		X			X		X		X		X		X	2	8	10
walk		X	X			X		X	X			X		X		X		X		X	2	8	10
will, going to, gonna		X		X	X		X			X		X		X		X		X		X	2	8	10
box		X	X			X	X		X			X		X		X		X		X	3	7	10
dog		X	X			X	X		X			X		X		X		X		X	3	7	10
friend		X	X		X			X		X	X			X		X		X		X	3	7	10
got to, have to, must, need, need to, should		X		X	X		X		X			X		X		X		X		X	3	7	10
have, had, own		X		X	X		X		X			X		X		X		X		X	3	7	10
look		X	X			X	X			X		X	X			X		X		X	3	7	10
up, rose (direction)		X	X		X			X		X		X		X		X		X	X		3	7	10
with		X		X	X		X		X			X		X		X		X		X	3	7	10
fast	X			X	X			X	X		X			X		X		X		X	4	6	10
high, tall	X		X		X		X			X		X		X		X		X		X	4	6	10
boat		X		X	X		X		X			X	X			X		X		X	4	6	10
dont know, doesnt know, did not know		X	X		X			X		X	X			X	X			X		X	4	6	10
down		X	X		X		X			X		X		X		X	X			X	4	6	10
how		X	X			X		X	X		X		X			X		X		X	4	6	10
me, I		X		X	X			X	X		X			X		X		X	X		4	6	10
not		X		X	X			X	X		X		X			X		X		X	4	6	10
run, ran		X		X	X		X		X		X			X		X		X		X	4	6	10
there		X	X		X		X			X		X	X			X		X		X	4	6	10
what		X	X		X		X			X		X	X			X		X		X	4	6	10

Continued on next page

Word	02Orange		03Gray		04Green		05Black		06Tiedye		07White		08Ivory		09Brown		10Yellow		11Purple		Totals		
	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	Both
kitten	X		X			X		X	X		X		X			X		X		X	5	5	10
little	X		X		X		X			X		X		X	X			X		X	5	5	10
out	X		X			X	X		X			X		X	X			X		X	5	5	10
airplane, plane		X	X			X	X		X		X		X			X		X		X	5	5	10
cow		X	X		X		X		X			X		X		X	X			X	5	5	10
day		X	X		X		X		X		X			X		X		X		X	5	5	10
go, went		X	X		X		X			X	X			X	X			X		X	5	5	10
home		X		X	X		X		X		X		X			X		X		X	5	5	10
on		X	X		X		X		X			X	X			X		X		X	5	5	10
egg	X		X		X		X		X			X	X			X		X		X	6	4	10
who	X		X		X		X		X			X	X			X		X		X	6	4	10
happy, glad, joy, please (make happy)		X	X		X		X		X			X	X		X			X		X	6	4	10
in, into		X	X		X		X		X			X	X			X		X	X		6	4	10
eat	X		X		X		X			X		X	X		X		X			X	7	3	10
like	X		X		X			X	X		X		X		X			X		X	7	3	10
my, mine	X		X		X			X	X		X		X		X			X		X	7	3	10
old	X		X		X		X		X		X		X			X		X		X	7	3	10
where	X			X	X		X		X		X		X		X			X		X	7	3	10
jump, hop		X	X		X		X		X		X		X		X			X		X	7	3	10
stop		X	X		X		X		X		X		X			X	X			X	7	3	10
bird	X		X		X		X		X		X		X		X			X		X	8	2	10
cat	X		X		X		X		X		X		X			X	X			X	8	2	10
mom, mommy, mother	X		X		X		X		X		X		X			X	X			X	8	2	10
no	X		X		X		X		X		X		X		X			X		X	8	2	10
now	X		X		X		X		X		X		X		X			X		X	8	2	10
sit	X		X		X		X		X		X		X		X			X		X	8	2	10
want	X		X		X		X		X		X		X		X			X		X	8	2	10
you	X			X	X		X		X		X		X		X			X	X		8	2	10
see, saw		X	X		X		X		X		X		X		X		X			X	8	2	10

Continued on next page

Word	02Orange		03Gray		04Green		05Black		06Tiedye		07White		08Ivory		09Brown		10Yellow		11Purple		Totals		
	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	Both
tree	X		X		X		X		X		X		X			X	X		X		9	1	10
yes	X		X		X		X		X		X		X		X		X			X	9	1	10
baby	X		X		X		X		X		X		X		X		X		X		10	0	10
car, drive, tractor, truck	X		X		X		X		X		X		X		X		X		X		10	0	10
can (able)		X		X		X		X		X		X		X		X		X			0	9	9
wish		X		X		X		X		X		X		X		X		X			0	9	9
stay		X		X		X	X			X		X		X		X		X			1	8	9
do not, dont		X		X	X		X			X		X		X				X		X	2	7	9
make, made		X		X	X		X		X			X		X		X		X			3	6	9
why		X		X	X		X		X			X	X			X				X	4	5	9
zoo		X		X	X		X		X		X		X			X		X			5	4	9
orange		X		X	X		X		X		X		X		X			X			6	3	9
sock		X	X		X		X		X		X		X			X		X			6	3	9
green	X		X		X		X		X		X		X		X					X	8	1	9
more		X	X		X		X		X		X		X		X		X				8	1	9
circus		X		X		X		X		X		X		X		X					0	8	8
tell, told		X		X	X			X		X		X		X		X					1	7	8
all, every		X		X	X			X	X			X		X		X					2	6	8
if, guess (suppose), suppose		X	X			X		X	X			X		X		X					2	6	8
put		X		X		X	X			X		X	X			X					2	6	8
sky, air			X			X		X	X			X		X		X				X	2	6	8
we		X		X	X			X		X		X	X		X						3	5	8
purple, violet		X	X			X	X		X			X	X			X					4	4	8
hat		X	X		X		X		X		X			X		X					5	3	8
new		X		X	X		X		X		X		X			X					5	3	8
blue		X	X		X		X		X		X		X			X					6	2	8
ball	X		X		X		X		X		X		X			X					7	1	8
when		X		X	X			X		X	X			X							2	5	7
good, well (good)	X		X		X		X		X		X			X							6	1	7
beaver				X		X		X		X		X		X							0	6	6

Continued on next page

Word	02Orange		03Gray		04Green		05Black		06Tiedye		07White		08Ivory		09Brown		10Yellow		11Purple		Totals		
	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	Both
care, mind				X		X		X		X		X		X							0	6	6
live, life, living				X		X		X		X		X		X							0	6	6
possum				X		X		X		X		X		X							0	6	6
hang				X		X		X	X			X		X							1	5	6
headache				X		X		X	X			X		X							1	5	6
leave (go), left (go)				X	X			X		X		X		X							1	5	6
very				X		X		X	X			X		X							1	5	6
funny				X	X			X	X			X		X							2	4	6
brother				X	X		X			X		X	X								3	3	6
exciting			X		X		X			X		X		X							3	3	6
flew, fly (like a bird)			X		X		X			X		X	X								4	2	6
sleep				X	X		X		X		X		X								5	1	6
bear, teddy bear			X		X		X		X		X		X								6	0	6
cold, cool, winter			X		X		X		X		X		X								6	0	6
work, chores			X		X		X		X		X		X								6	0	6
a lot (many), many				X		X		X		X		X									0	5	5
bunny				X		X		X		X				X							0	5	5
dont want, does not want				X		X		X		X		X									0	5	5
easy				X		X		X		X				X							0	5	5
least, at least				X		X		X		X				X							0	5	5
most				X		X		X		X				X							0	5	5
only, just				X		X		X		X				X							0	5	5
really				X		X		X		X				X							0	5	5
thing, stuff (things)				X	X			X		X		X									1	4	5
try, tried				X		X		X	X					X							1	4	5
ear				X	X			X	X					X							2	3	5
pig						X	X			X		X	X								2	3	5

Continued on next page

Word	02Orange		03Gray		04Green		05Black		06Tiedye		07White		08Ivory		09Brown		10Yellow		11Purple		Totals		
	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	Both
sister				X	X			X		X			X								2	3	5
carrot			X		X		X			X				X							3	2	5
cook			X		X		X		X				X								5	0	5
sad			X		X		X		X				X								5	0	5
decide				X		X		X		X											0	4	4
dirt, mud				X		X		X		X											0	4	4
hurry						X		X		X		X									0	4	4
skunk				X		X		X		X											0	4	4
did not like, dont like						X	X			X				X							1	3	4
deer, moose, reindeer				X	X		X		X												3	1	4
fork						X		X		X											0	3	3
hand						X		X		X											0	3	3
juice						X		X		X											0	3	3
net						X		X		X											0	3	3
sandal						X		X		X											0	3	3
upstairs					X			X		X											1	2	3
dad, daddy, father					X		X			X											2	1	3
gun, pistol						X	X		X												2	1	3
nice, nicest					X			X	X												2	1	3
sun						X	X		X												2	1	3
drink, drank					X		X		X												3	0	3
water					X		X		X												3	0	3
downstairs						X		X													0	2	2
mess						X		X													0	2	2
pants, jeans						X		X													0	2	2
toast						X				X											0	2	2
top						X		X													0	2	2
beach						X	X														1	1	2
bite, bit					X					X											1	1	2
breakfast					X			X													1	1	2

Continued on next page

Word	02Orange		03Gray		04Green		05Black		06Tiedye		07White		08Ivory		09Brown		10Yellow		11Purple		Totals		
	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	Both
bucket, pail, tin can (bucket)					X			X													1	1	2
dress, dressed						X	X														1	1	2
hit					X			X													1	1	2
off						X	X														1	1	2
six						X			X												1	1	2
wash, washed					X					X											1	1	2
dig					X				X												2	0	2
later					X		X														2	0	2
morning					X		X														2	0	2
shoes					X		X														2	0	2
time					X		X														2	0	2
fly (through the air)						X															0	1	1
fun						X															0	1	1
light						X															0	1	1
not yet						X															0	1	1
over						X															0	1	1
shorts						X															0	1	1
again					X																1	0	1
careful, carefully					X																1	0	1
come, came, back (return)					X																1	0	1
do-do					X																1	0	1
face					X																1	0	1
hello					X																1	0	1
house					X																1	0	1
hungry					X																1	0	1
night					X																1	0	1
one					X																1	0	1
shirt					X																1	0	1
to, toward					X																1	0	1

Continued on next page

Word	02Orange		03Gray		04Green		05Black		06Tiedye		07White		08Ivory		09Brown		10Yellow		11Purple		Totals		
	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	K	S	Both
two					X																1	0	1
under					X																1	0	1
yellow					X																1	0	1

APPENDIX F

PRE-STUDY QUESTIONNAIRE

Participant #_____

PRE-STUDY QUESTIONNAIRE

1. How old are you? _____

2. How many children do you have? Which child is deaf/hard of hearing?

   _____

3. How old is your deaf or hard of hearing child? _____

4. At what age was s/he identified? _____

5. Is anyone else in your family deaf or hard of hearing? If so, list. _____

   _____

6. How long have you been learning sign language?

   _____

7. What motivated you to learn sign language?

   _____

   _____

8. Rate your comfort when signing to communicate with a Deaf adult. (Mark your response on the line with an X)

|_____|_____|_____|_____|_____|_____|

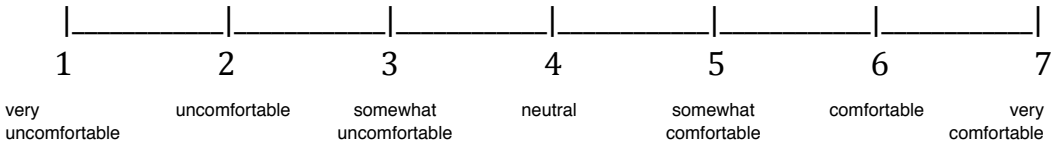
1	2	3	4	5	6	7
very uncomfortable	uncomfortable	somewhat uncomfortable	neutral	somewhat comfortable	comfortable	very comfortable

9. Rate your comfort recognizing a Deaf adult's signs. (Mark your response on the line with an X)

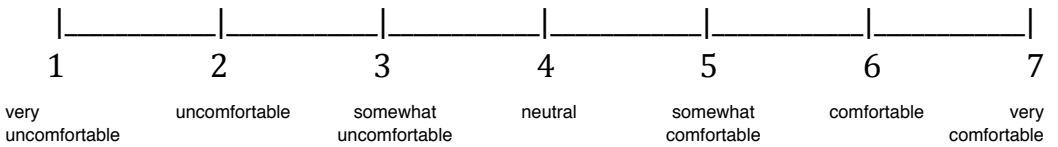
|_____|_____|_____|_____|_____|_____|

1	2	3	4	5	6	7
very uncomfortable	uncomfortable	somewhat uncomfortable	neutral	somewhat comfortable	comfortable	very comfortable

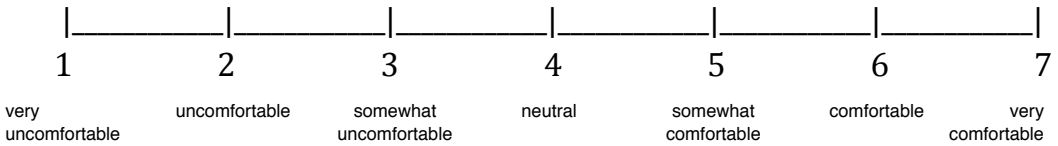
10. Rate your comfort when signing to communicate with <u>your child</u>. (Mark your response on the line with an X)



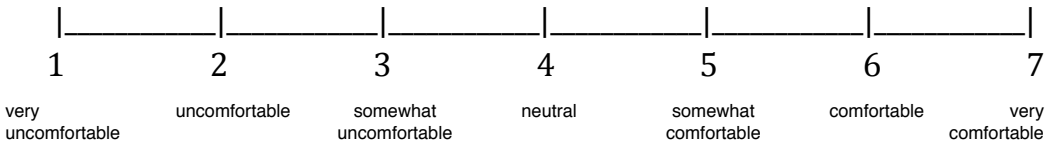
11. Rate your comfort recognizing a <u>your child</u>'s signs. (Mark your response on the line with an X)



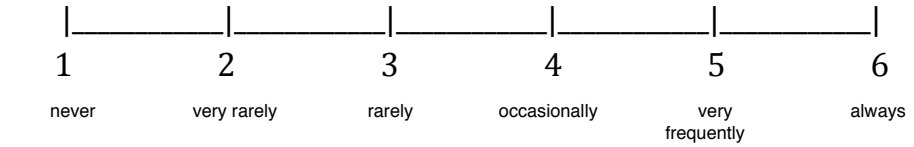
12. Rate your comfort when signing to communicate with <u>other parents of deaf children</u>. (Mark your response on the line with an X)



13. Rate your comfort recognizing <u>other parents of deaf children</u>'s signs. (Mark your response on the line with an X)



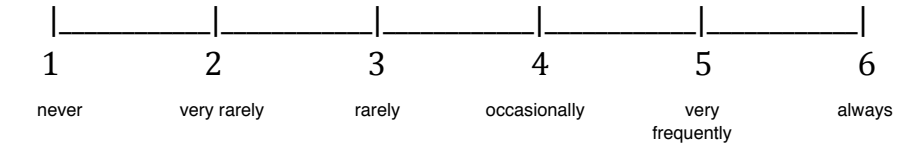
14. How frequently do you sign with your child versus using other methods? (Mark your response on the line with an X)



15. What other methods do you use?

_____

16. How frequently do you sign with <u>people other than your child</u>? (Mark your response on the line with an X)



10. List these people.

_____

11. Are you right handed or left-handed? Circle one.

right left

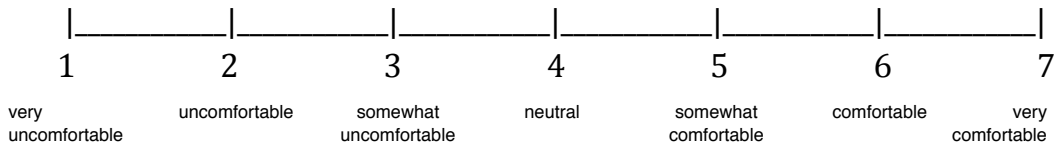
APPENDIX G

POST-STUDY QUESTIONNAIRE

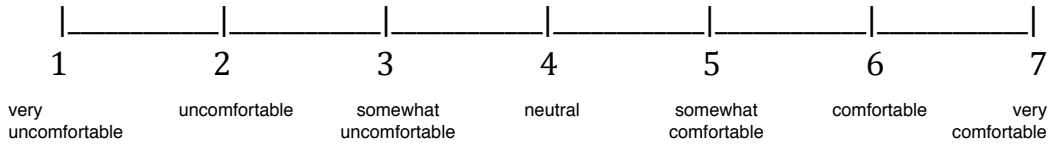
Participant #_____

POST-STUDY QUESTIONNAIRE

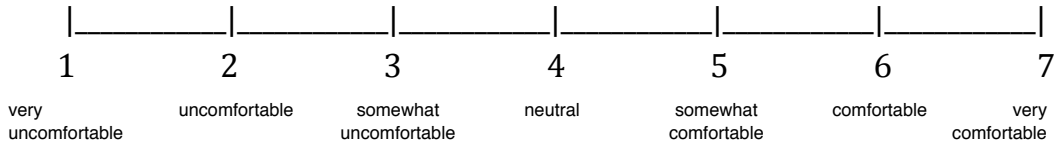
1. Rate your comfort when signing to communicate with a Deaf adult. (Mark your response on the line with an X)



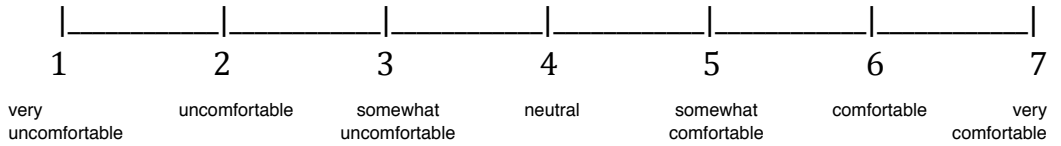
2. Rate your comfort recognizing a Deaf adult's signs. (Mark your response on the line with an X)



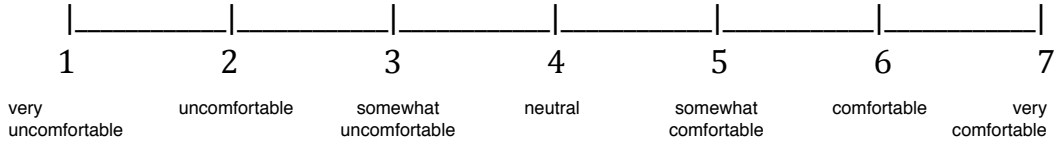
3. Rate your comfort when signing to communicate with your child. (Mark your response on the line with an X)



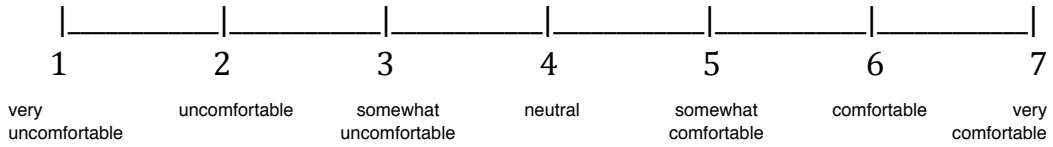
4. Rate your comfort recognizing your child's signs. (Mark your response on the line with an X)



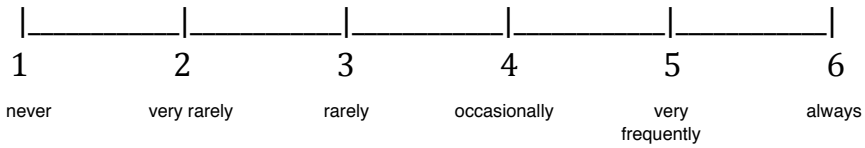
5. Rate your comfort when signing to communicate with other parents of deaf children.(Mark your response on the line with an X)



6. Rate your comfort recognizing <u>other parents of deaf children</u>'s signs. (Mark your response on the line with an X)



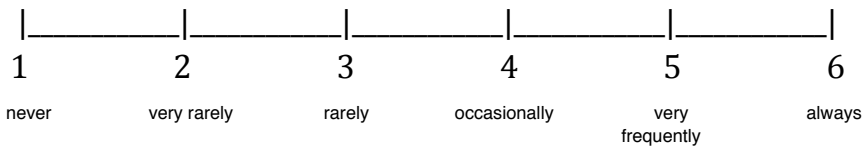
7. How frequently do you sign with your child versus using other methods? (Mark your response on the line with an X)



8. What other methods do you use?

_____

9. How frequently do you sign with <u>people other than your child</u>? (Mark your response on the line with an X)



10. List these people.

_____

11. I think that I would like to use SMARTSign frequently. (Mark your response on the line with an X)

|_____|_____|_____|_____|

1 2 3 4 5

strongly disagree | disagree | neutral | agree | strongly agree

12. I found SMARTSign unnecessarily complex. (Mark your response on the line with an X)

|_____|_____|_____|_____|

1 2 3 4 5

strongly disagree | disagree | neutral | agree | strongly agree

13. I thought SMARTSign was easy to use. (Mark your response on the line with an X)

|_____|_____|_____|_____|

1 2 3 4 5

strongly disagree | disagree | neutral | agree | strongly agree

14. I think I would need the support of a technical person to be able to use SMARTSign.

|_____|_____|_____|_____|

1 2 3 4 5

strongly disagree | disagree | neutral | agree | strongly agree

15. I found the various functions in SMARTSign were well integrated. (Mark your response on the line with an X)

|_____|_____|_____|_____|

1 2 3 4 5

strongly disagree | disagree | neutral | agree | strongly agree

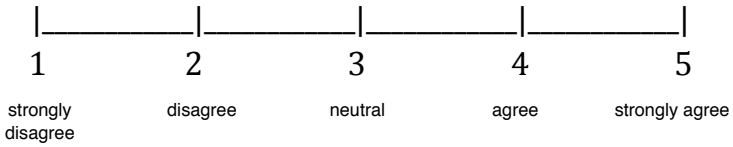
16. I thought SMARTSign was too inconsistent. (Mark your response on the line with an X)

|_____|_____|_____|_____|

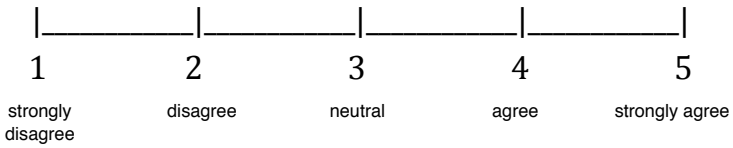
1 2 3 4 5

strongly disagree | disagree | neutral | agree | strongly agree

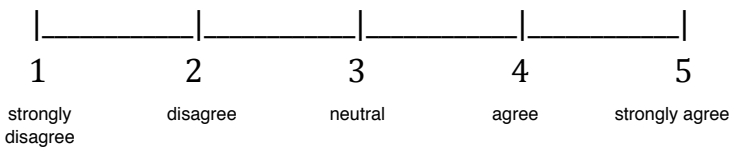
17. I would imagine that most people would learn to use SMARTSign very quickly. (Mark your response on the line with an X)



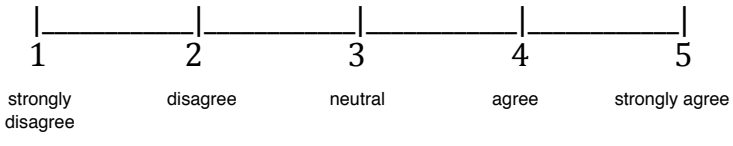
18. I found SMARTSign very cumbersome to use. (Mark your response on the line with an X)



19. I felt very confident using SMARTSign. (Mark your response on the line with an X)



20. I needed to learn a lot of things before I could get going with SMARTSign. (Mark your response on the line with an X)



21. Any other comments you would like to share?

_____

_____

_____

_____

APPENDIX H

PARTICIPANT SMARTSIGN USAGE

This appendix shows graphs of what components participants used on specific days of the study. Boxes are drawn around the days of the 2-week meeting and the final meeting.

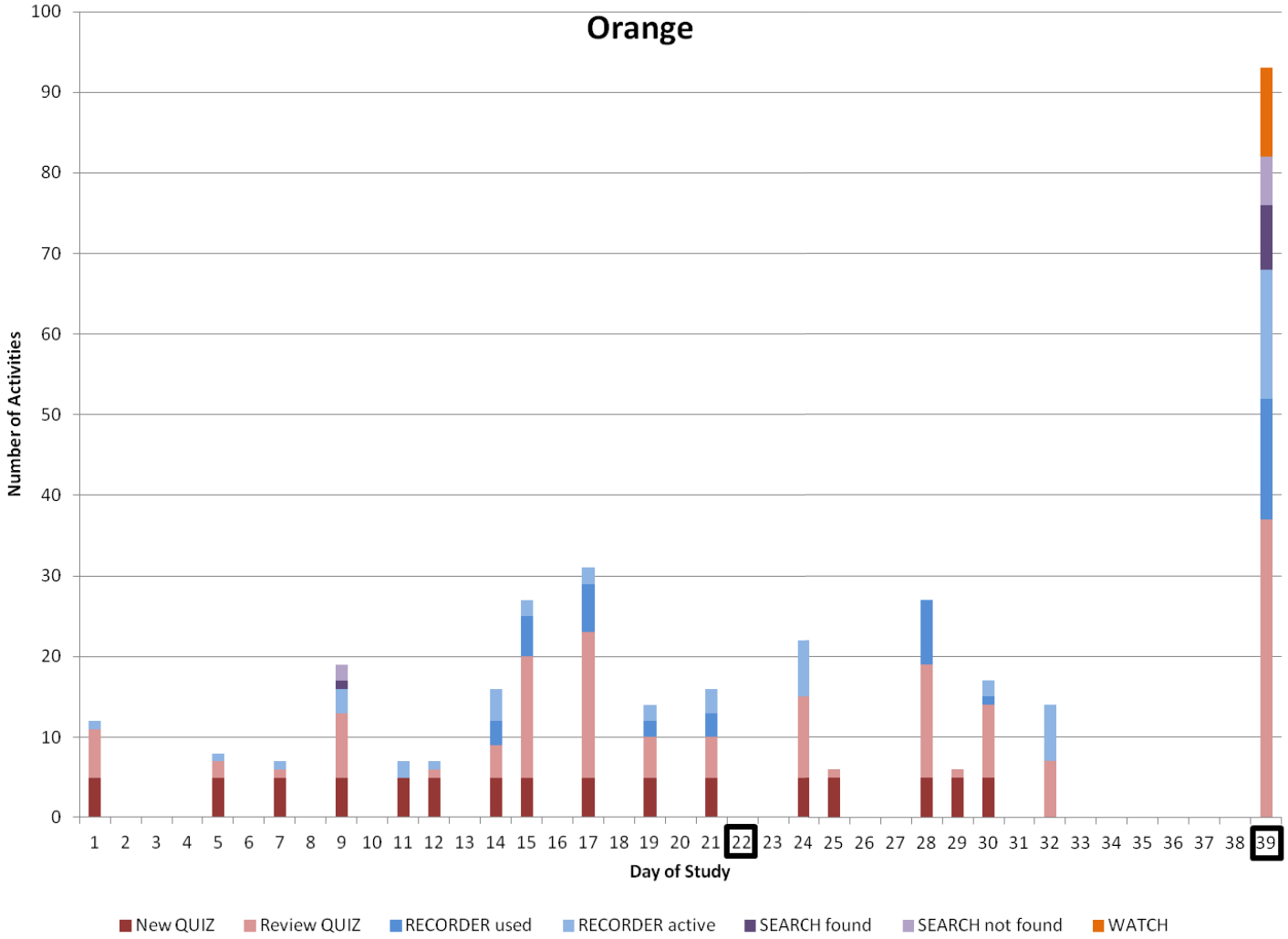


Figure 48: Graph of Mr. Orange's SMARTSign usage

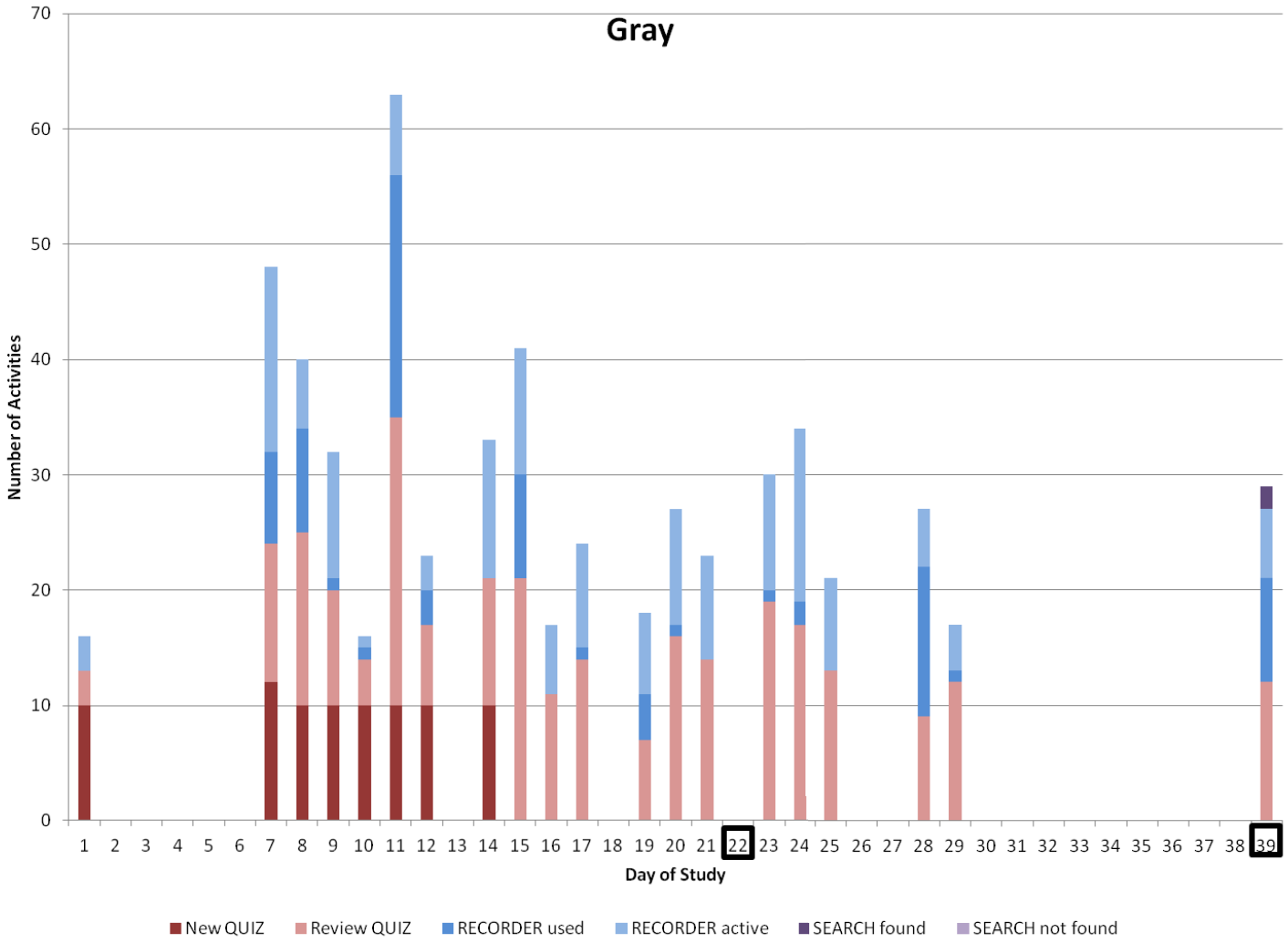


Figure 49: Graph of Mrs. Gray's SMARTSign usage

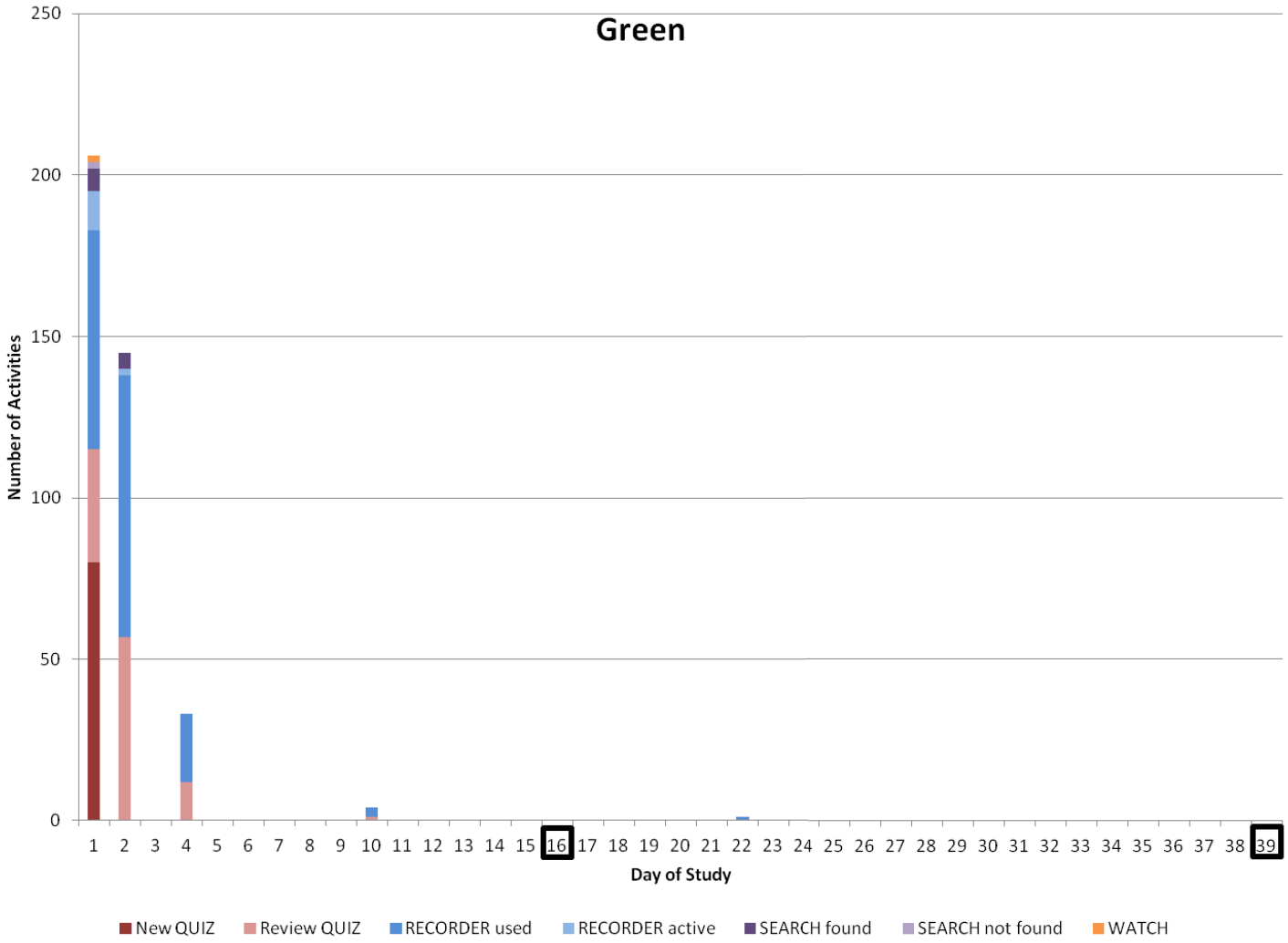


Figure 50: Graph of Mrs. Green's SMARTSign usage

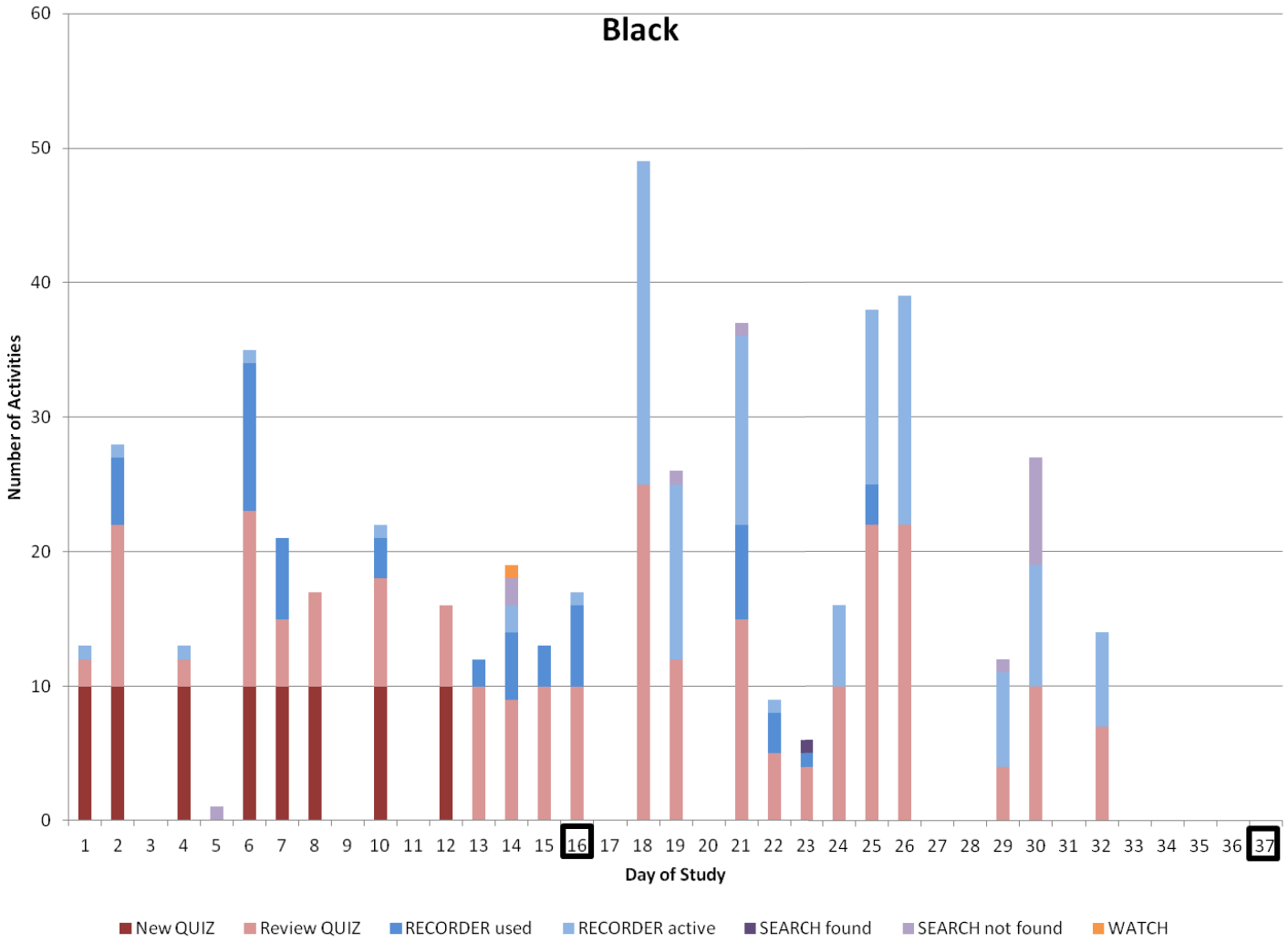


Figure 51: Graph of Mrs. Black's SMARTSign usage

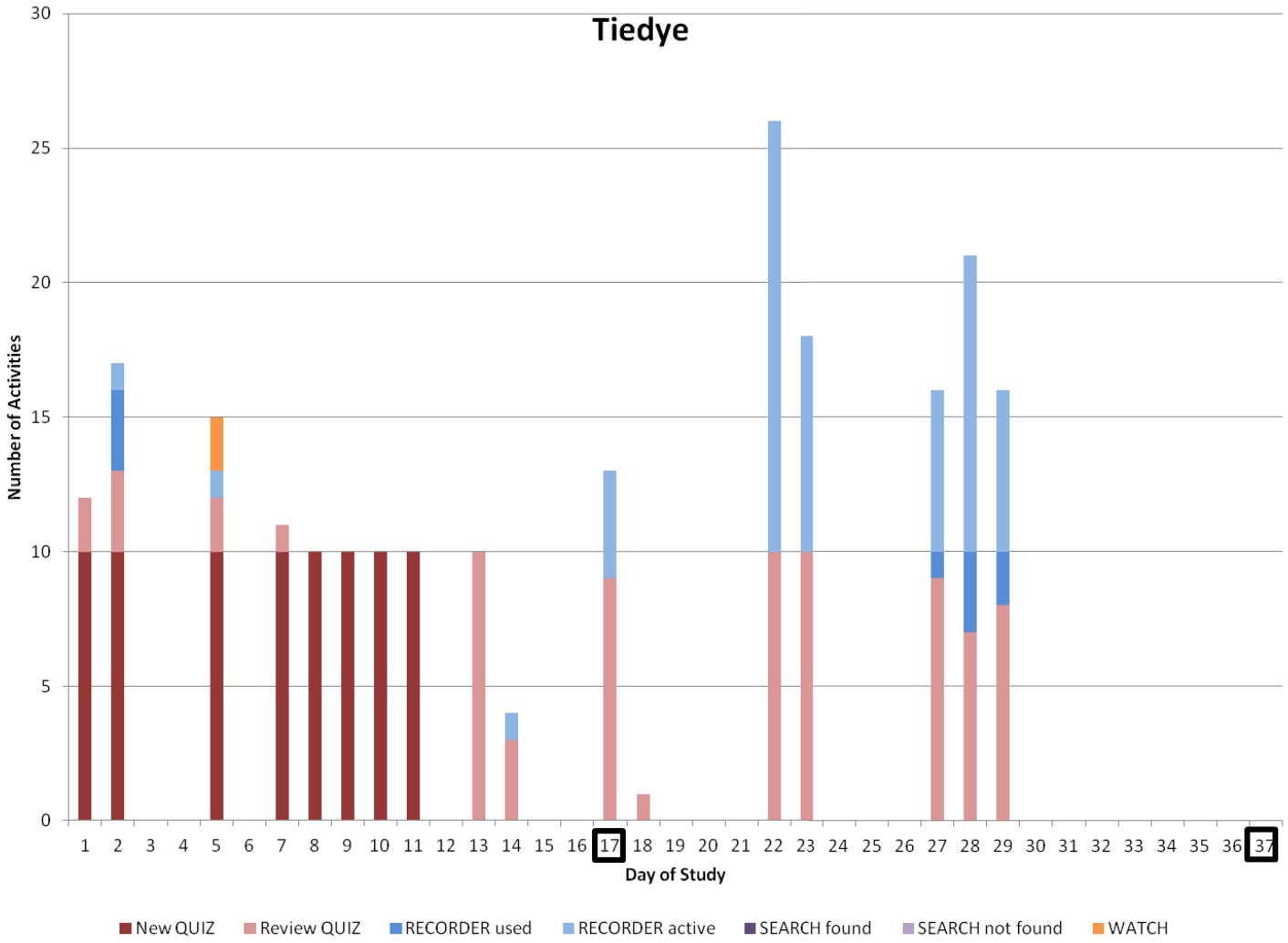


Figure 52: Graph of Mrs. Tiedye's SMARTSign usage

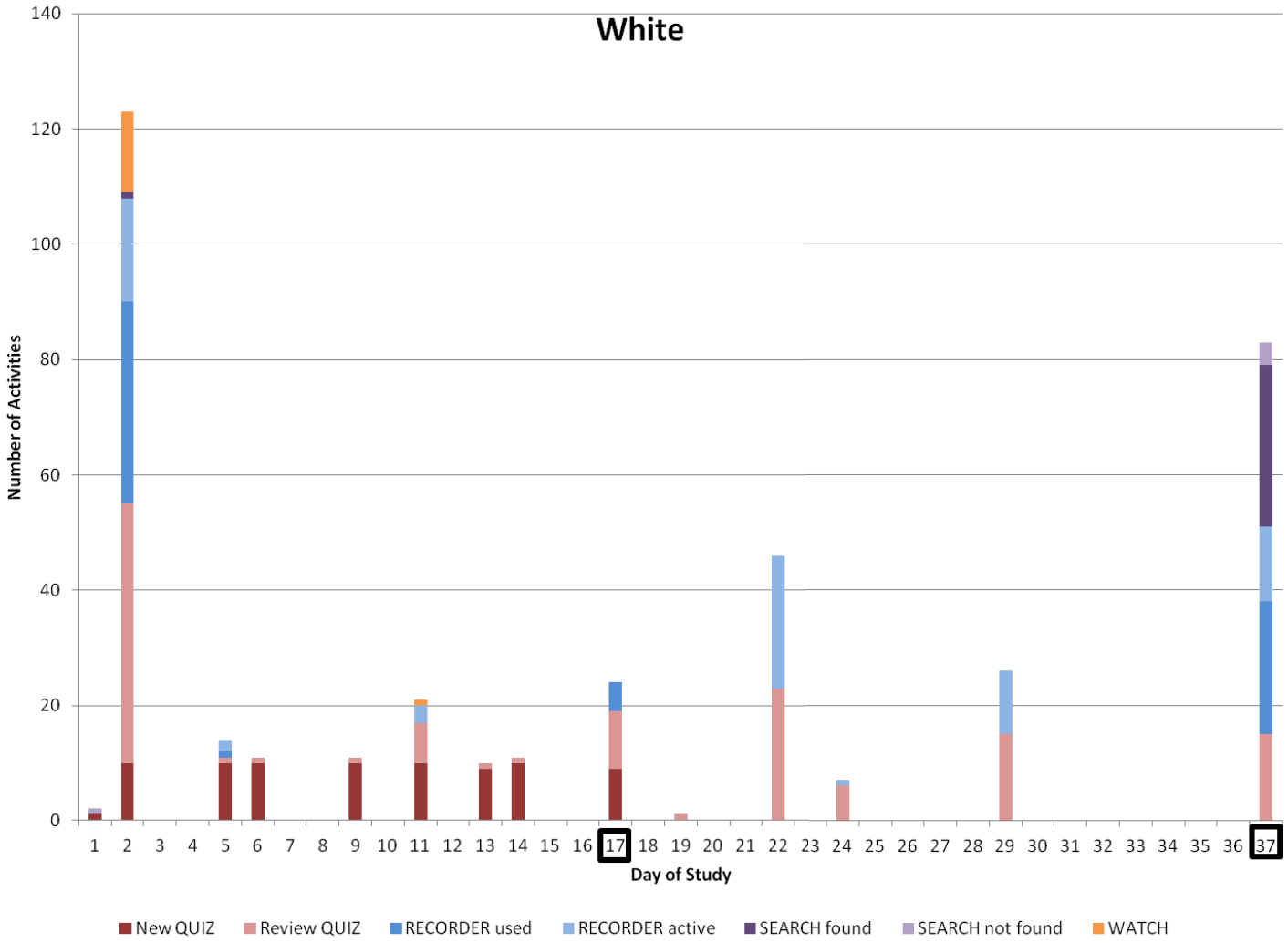


Figure 53: Graph of Mr. White's SMARTSign usage

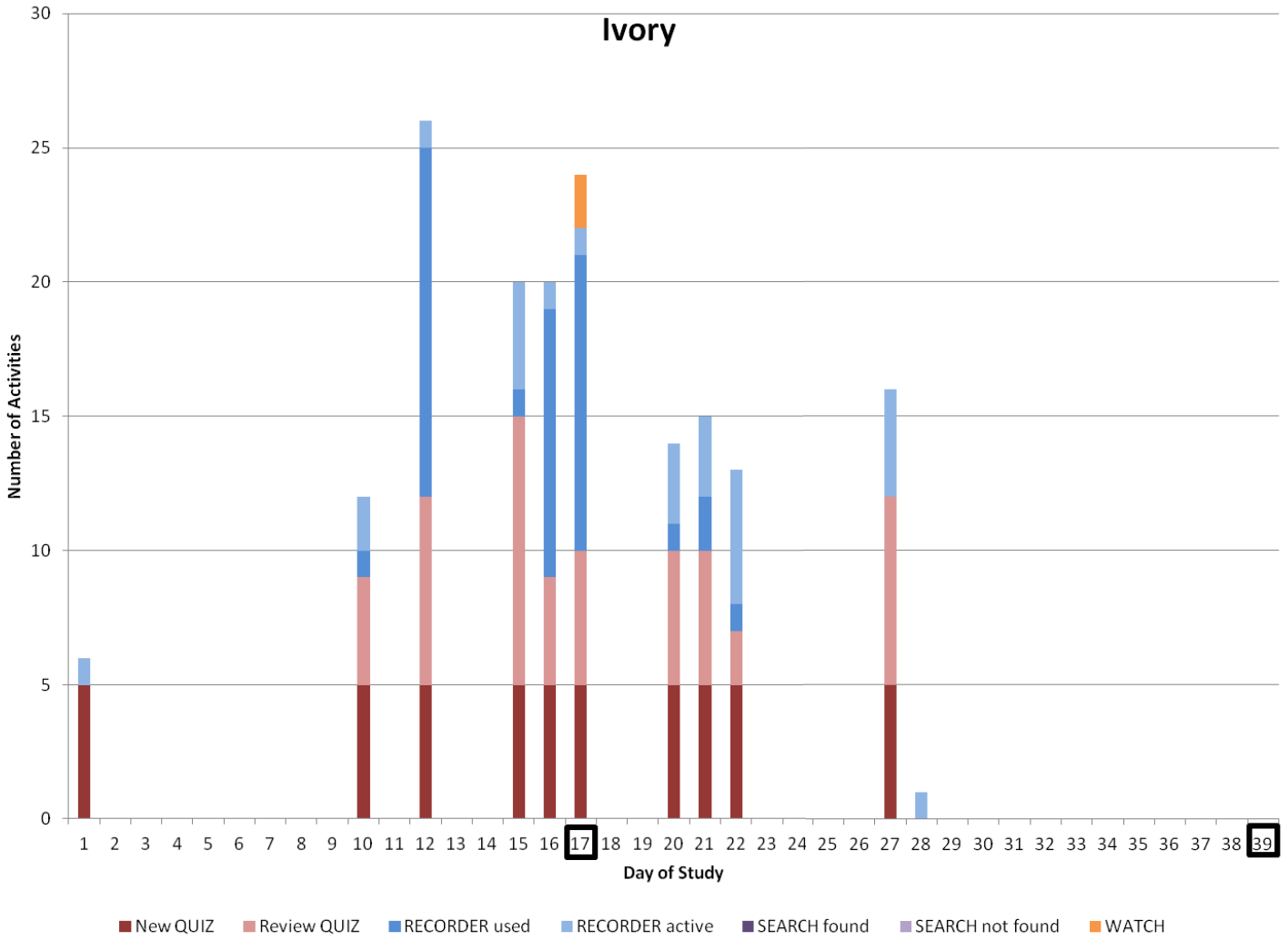


Figure 54: Graph of Mrs. Ivory SMARTSign usage

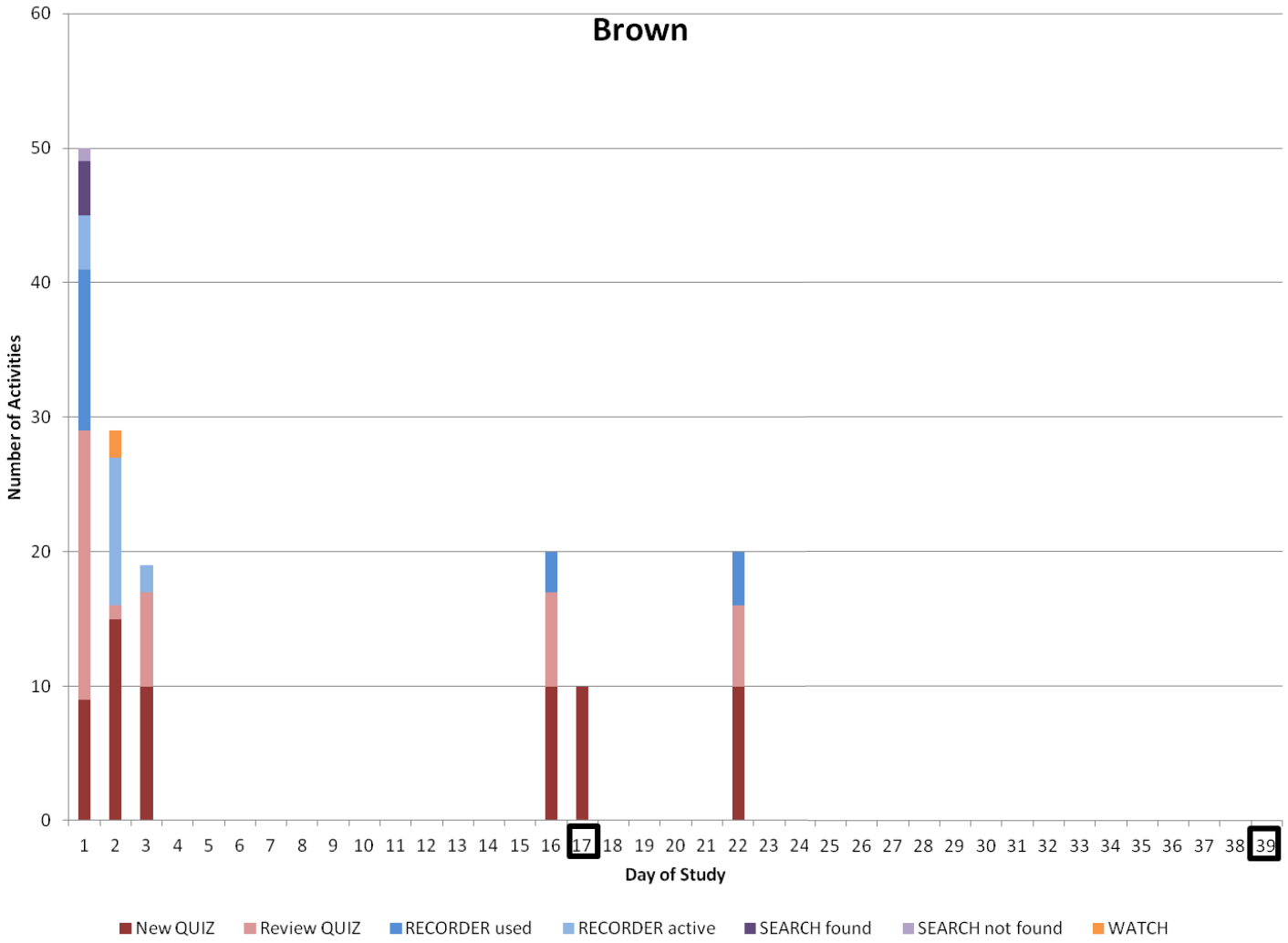


Figure 55: Graph of Mr. Brown's SMARTSign usage

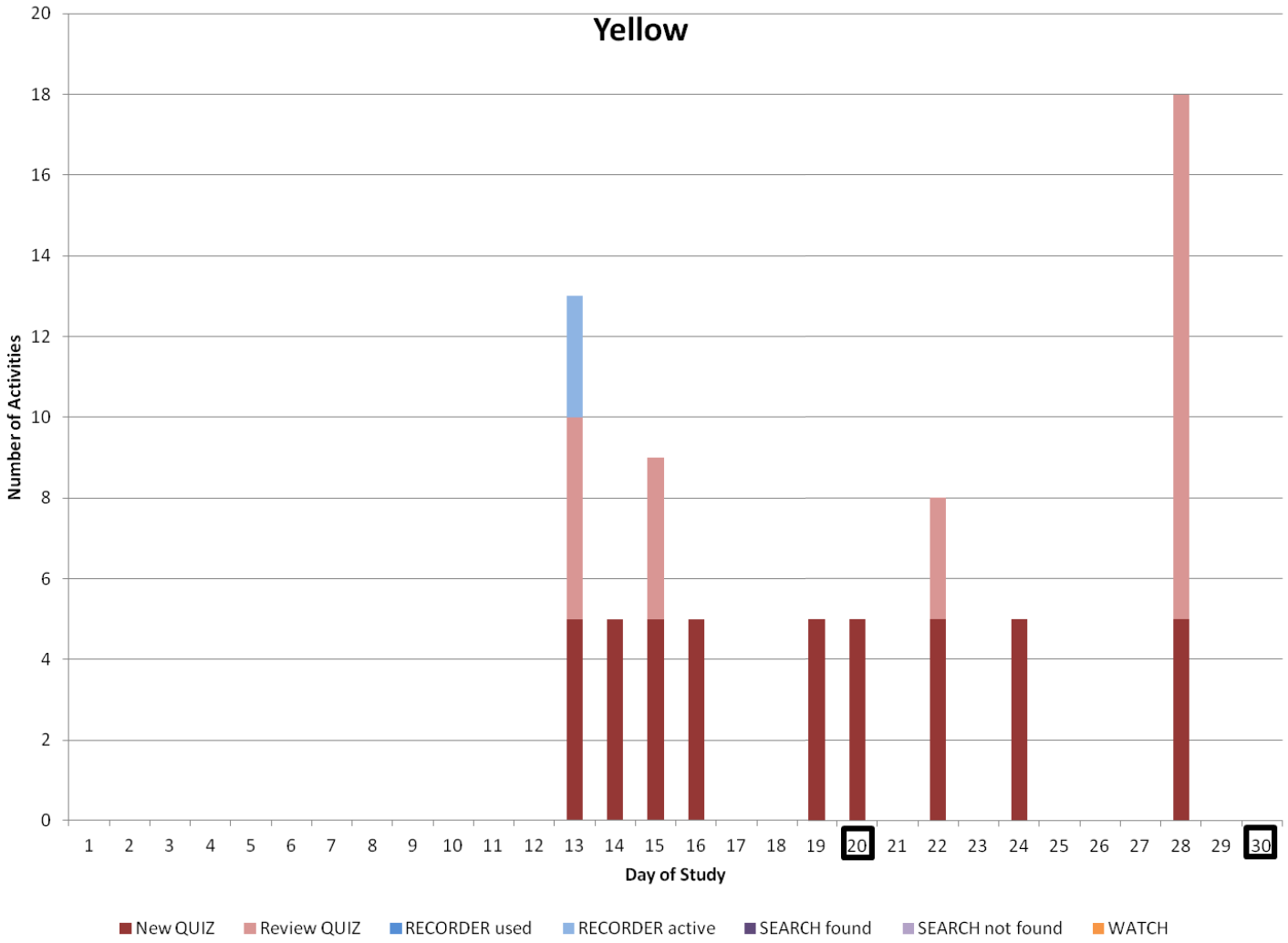


Figure 56: Graph of Mrs. Yellow SMARTSign usage

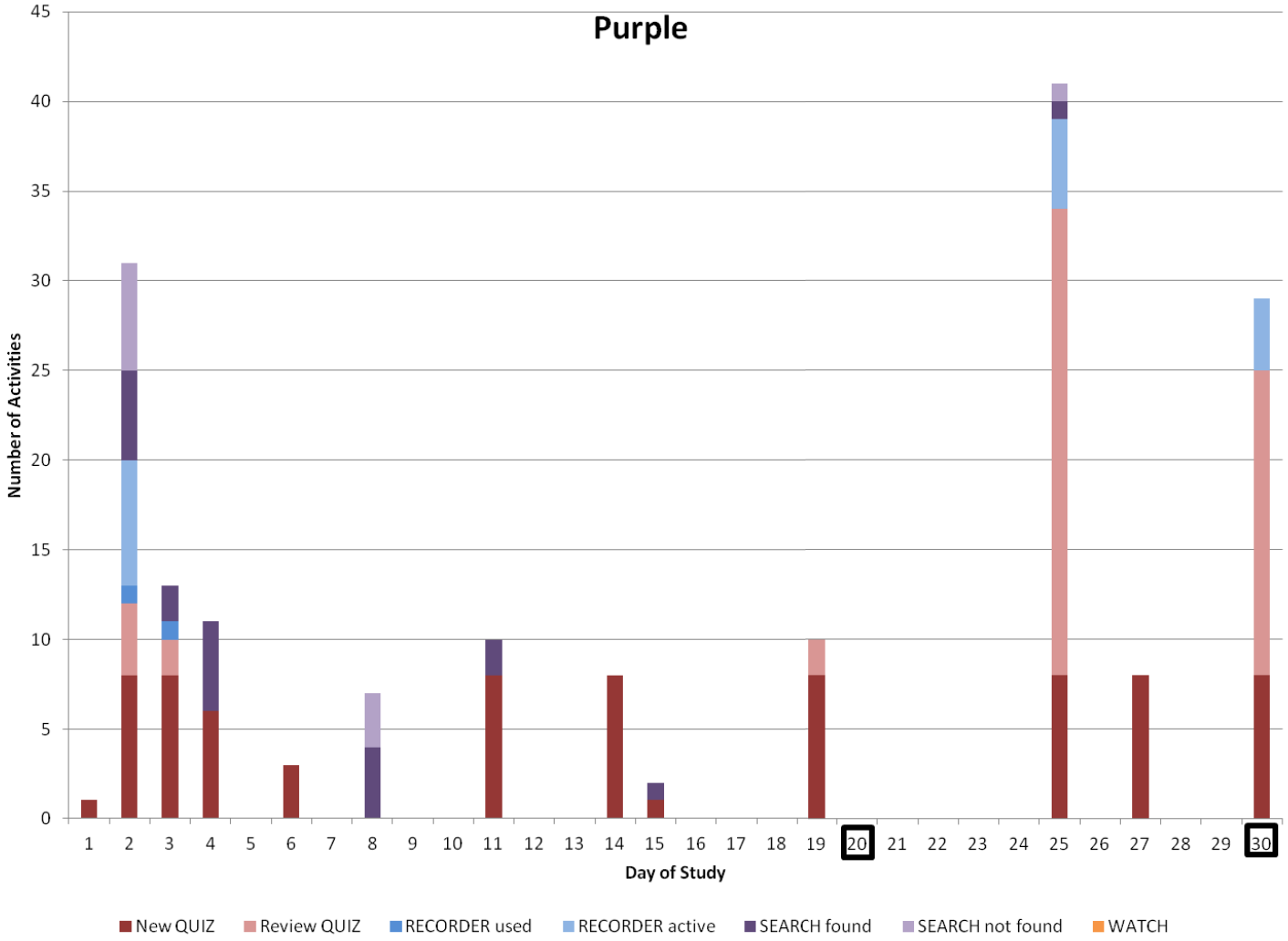


Figure 57: Graph of Mr. Purple's SMARTSign usage

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